SEASONAL ABUNDANCE AND DIVERSITY OF NEARSHORE FISHES AROUND STELLER SEA LION HAULOUTS OF KODIAK ISLAND

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A

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Abstract:

Nearshore fishes around haulouts are potential prey for Steller sea lions, especially pups, as they learn to forage and supplement their milk diets during weaning. Visual surveys in July and November 2001, and March, May and July 2002 were used to quantify spatial and temporal variation in fish diversity and abundance around two Steller haulouts and two control sites. SCUBA divers sampled depths of 9, 15, 21, 27, and 33 m. Concurrent habitat surveys were used to quantify substrate, macroalga and benthic invertebrate cover. Steller haulout sites had fewer fish than control sites, but similar species richness and species composition at the 9, 15 and 21 m depths during the summer sampling periods. In winter, fish were fewer but more evenly distributed. Habitats were not significantly different between Steller haulouts and control sites. All sites had seasonal cover of canopy forming kelp, and overstory algal cover was heavy down to 21 m. At approximately 27 m the habitat changed abruptly from kelp-covered bedrock to bare gravel and shell hash. While nearshore fish are an important component of Steller diets, results from this study do not indicate that fish assemblages at haulouts are substantially different from other headland sites.

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Introduction:

Since the late 1960s, the world population of Steller sea lions (*Eumetopias jubatus*), hereafter referred to as Stellers, declined from 282,000 to less than 100,000 individuals for still unknown reasons (Calkins and Goodwin 1988, Loughlin et al. 1992, Trites and Larkin 1996, Sease and Loughlin 1999). Stellers have not suffered this decline equally across their entire range in the North Pacific Ocean. The species is subdivided into genetically distinct Western and Eastern stocks at Cape Suckling, Alaska (144 °W longitude, Figure 1) (NMFS 1995, Loughlin 1997, NMFS 1997). Since Stellers usually return to their natal rookery to breed, there is very little mixing between the two stocks (Calkins and Pitcher 1982, Raum-Suryan et al. 2002). The Eastern stock, although occupying a smaller population area, has recently increased in number primarily in southeast Alaska. As a result of these increases, this stock of Stellers was never changed from threatened to endangered (Trites and Larkin 1996). The Western stock has experienced the most drastic decline, approximately 80% since the late 1960's (Calkins and Goodwin 1988, Loughlin et al. 1992, Trites and Larkin 1996, Sease and Loughlin 1999). This stock was classified as endangered in 1997 under the Endangered Species Act (NMFS 1997). Most of the decline of the Western stock was centered around Kodiak Island and westward of Kodiak in the Eastern Aleutian Islands (Trites and Larkin 1996).

In the 1990's, the annual rate of the Western stock decline slowed to about of 4% per year. 2002 survey data of the Western stock showed the first

region wide increase since standardized aerial surveys began in the 1970's, although counts are still down 30% since 1990 (Sease and Gudmundson 2002). However, both the factors causing the initial decline and the change in the rate of decline are still unknown. One hypothesis is that Steller sea lion declines resulted from nutritional stress related to the quantity or quality of prey available within their critical habitat (ASG 1993, NMFS 1995, Sease and Merrick 1997, Merrick et al. 1997, Calkins et al. 1998, Springer 1998, Benson and Trites 2002 although see NRC 2003, Springer et al. 2003). Particularly, it is believed that survival between weaning and adulthood was somehow compromised (Merrick 1995, Sease and Merrick 1997).

Critical habitat for any species includes those areas that provide prey and shelter for mothers and their dependent young (Moen 1973). Under the 1993 ESA listing, critical habitat for the western stock of Stellers was delineated to include the rookeries (terrestrial areas used for breeding and pupping) and major haulouts (for resting) and the surrounding twenty nautical miles of surrounding water west of 144° W longitude (50 CFR 226.202). This habitat was thought to provide sufficient prey resources for mothers whose foraging range is restricted by their need to return to rookeries or haulouts to suckle pups and for weaning pups whose foraging range may be physiologically limited (50 CFR 226.202). The waters immediately surrounding the haulouts may also be particularly critical to inexperienced pups as they learn to forage, are weaned and eventually become independent of their mothers.

Steller weaning is thought to be a variable and extended process, lasting from 6 to 23 months (Porter 1997, Trites and Porter 2002). Through the pup's first winter, the bulk of its nutritional needs are probably obtained from its mother who returns to suckle between foraging trips that last from three to eight days, with the mother taking longer foraging trips in the winter (Merrick and Loughlin 1997, Trites and Porter 2002). Stable isotope analysis indicates that young-of-the-year Stellers (0-9 months) supplement the mother's milk with increasing foraging activity during the protracted weaning process (Hirons 2001). Young-of-the-year Stellers, between the ages of 9-10 months, (tagged in March) made dives to approximately 4 to10 m (M. Rehburg and J. Burns University of Alaska Anchorage unpubl. data, Merrick and Loughlin 1997, Loughlin et al. 2003). Two months later, at approximately one year of age, these same animals dove to approximately 33 to 50 m (Loughlin et al. 2003). It is hypothesized that as weaning, young-of-the-year Stellers mature, they may start exploring and foraging immediately around their haulouts, supplementing their milk diet with shallow subtidal or intertidal demersal prey species.

Young-of-the-year and yearling Stellers spend approximately 80% of their time on the haulouts (Merrick and Loughlin 1997, M. Rehburg and J. Burns; University of Alaska Anchorage, unpubl. data). Time in the water is spent making shallow dives of 4 to10 m (Merrick and Loughlin 1997, Loughlin et al. 2003, Rehburg and Burns unpubl. data) often in the nearshore water within 100 meters of the haulout (K. Wynne; University of Alaska Fairbanks, pers. comm.).

As they gain more nutritional independence from their mother, they range further afield, but still stay in the shallow (<100 m depth) nearshore water (Loughlin et al. 2003). Despite scientific evidence indicating that the young-of-the-year Stellers are in a critical stage of their life history during the protracted weaning process and immediately following weaning as they develop their physiological diving capacity (Merrick 1995, Sease and Merrick 1997, Burns and Rhea unpubl. data), little is known about food availability in the shallow, nearshore waters around haulouts.

Extensive use of nearshore waters around Kodiak Island haulouts by Stellers has been documented visually and telemetrically. Data collected in 2000 from Steller pups captured on Long Island and equipped with satellite-linked depth recorders by the National Marine Mammal Lab (NMML) and the Alaska Department of Fish and Game (ADFG) show young-of-the-year pups and yearlings remain primarily on or near the Long Island or nearby Cape Chiniak haulouts and make relatively shallow dives through early spring. (Loughlin et al. 2003, Rehburg and Burns unpubl. data). In April these and other identifiable pups have been observed suckling (still at least partially nutritionally dependent on mother) on Long Island and swimming and playing within 100 m of the haulout (Wynne pers. comm.).

Diets of marine mammals, including Stellers, are documented by analysis of hard or bony parts of the prey that are found in fecal remains (scats) on the haulouts or rookeries. Due to a difference in passage rates among hard parts of

different fish species, Tollit et al. (2003) found that one scat may represent a composite of several "meals" over the course of more than one day. Although the different passage rates complicate matters, current (1999-2000) Steller scat analysis from the Cape Chiniak and Long Island haulouts near Kodiak indicate what are perhaps two foraging strategies, or life-stage related diet compositions (K. Wynne, University of Alaska Fairbanks; unpubl. data). One type is composed primarily of deepwater species, such as Pollock, *Theragra chalcogramma*, arrowtooth flounder, *Atheresthes stomias*, and seasonal forage fish. Other scats, although also showing seasonal forage fish use, also contains otoliths or other hard parts from the numerous species that are considered nearshore or even intertidal (Wynne et al. 2003). Although it is not possible to ascertain the scat depositor's age, it is hypothesized that subtidal species would show up more frequently in scats of pups learning to forage in shallow nearshore waters than in scats of older animals. The most frequently occurring prey remains in scats from the Long Island and Cape Chiniak haulouts varies seasonally but includes flatfish (arrowtooth flounder and soles), gadids (walleye pollock and Pacific cod), cephalopods, cottids (Irish lords), and forage fish (primarily sandlance, but also capelin and herring) (Wynne et al. 2003). Some of the most frequently occurring prey groups in Steller scats from four eastern Kodiak Island haulouts are considered to be shallow subtidal or intertidal species, including gunnels, greenling, sandlance, and Irish lords (Eschmeyer and Herald 1983). Ronquils, snailfish, poachers, cockscombs, and other inter- or subtidal fish species were

found less frequently in the scats. Many of the flatfish, gadid, and cottid fish species found in Steller diets use nearshore waters and kelp beds for spawning, rearing and shelter (Eschmeyer and Herald 1983).

The headland nearshore waters of Kodiak Island, such as those waters surrounding the Steller haulouts, typically have thick kelp cover (Calvin and Ellis 1978). Some of the factors that determine macroalgal bed densities and species compositions are light attenuation at depth, wave exposure and substrate suitability (Foster and Schiel 1985). The factors that affect macroalgal growth can vary over the geographical range of an alga and cause localized variability in kelp beds. Variability in macroalgal cover affects the fish fauna that inhabit kelp beds (Foster and Schiel 1985). Although there is little documentation of Kodiak Island kelp beds and the fish that inhabit them, kelp beds in some other parts of the world have been well documented. Fish use kelp beds or other densely vegetated areas for a variety of reasons, depending on the species and age of the fish and the type of vegetative cover (North and Hubbs 1968, Hobson and Chess 1976, Ebeling and Laur 1985, Hay 1985, Schmitt and Holbrook 1985, Singer 1985, Carr 1989, Merrill 1989, Love et al. 1991, Levin 1991, Carr 1992). Studies of fish and algal populations along the coast of California and Washington provide a guideline for the ecological patterns associated with kelp habitats in Alaska. Alaska is known to have a wide range of kelp bed types (O'Clair and Lindstrom 2000) that support a high diversity of fish (Murphy et al. 2000, Dean et al. 2000).

To test the hypothesis that haulouts were used by female Stellers with pups because of a difference in the nearshore fish fauna, I estimated fish species composition and abundance immediately adjacent to two Steller haulouts in the Kodiak area: Long Island and Cape Chiniak. For comparison, control surveys were conducted around two rocky headlands in the Chiniak Bay area that are not used as haulouts by Stellers. The objectives of this research were to seasonally identify and quantify the nearshore fish at discrete depths at both Steller haulouts and control areas. I also identified and quantified the seasonal habitat, including macroalgal cover, substrate and sessile invertebrates at the sampled depths.

Specific hypotheses that were addressed statistically include:

- H_O: There is no statistically significant difference between the fish fauna at Steller haulout and non-haulout sites.
- H_O: Difference in the fish populations between Steller and non Steller haulout sites cannot be explained by corresponding differences in the habitat as described by macroalgal cover, substrate, and benthic invertebrate fauna.

Methods

Study location:

Kodiak Island, which has one Steller rookery and 11 historical haulouts, is located at 57° 27' N, 153°22' W off the south-central coast of Alaska (Figure 2). Three major islands are in the Kodiak archipelago (Shuyak, Kodiak and

Afognak), thousands of small islands and rocks, and numerous bay systems. The strong currents along the eastern side of the island are predominately tidal, with velocities of 150 cm/sec or more (MacDonald 1979). The tidal amplitude of the eastern side is in the range of 2-4 m and that, combined with an effective fetch to the southeast of approximately 1,850 km, makes wave action at headlands severe.

Study sites:

Four study sites, including two haulout sites and two control sites, off the east side of Kodiak Island were chosen based on known patterns of use by Stellers and similar physical characteristics such as bathymetry, substrate, and exposure. All four sites are situated on rocky headlands with eastern wave exposure (Figure 3). Long Island and Cape Chiniak are historical Steller haulouts, while Hanin Rocks and Queer Island are not and, as such, were chosen as control sites. Each site was sampled at 9, 15, 21, 27 and 33 m depth, within a 100 m radius of the haulouts at Steller sites, and within 100 meters of the headland at the non-haulout sites. These depths were chosen to correspond with dive profiles of young-of-the-year Stellers studied by ADFG and NMML, both prior to our sampling and concurrent with this study. These two haulouts are primarily used from September to June by females with pups and are the focus of an integrated study of Steller sea lion prey availability and use (Wynne and Foy 2002) and pup foraging behavior (ADFG and NMML unpubl. data).

Temporal sampling design:

Sites were sampled in ten to fourteen day blocks during July and November 2001; and March, May and July 2002. These sampling periods were chosen to coincide both with key stages in the life history of Stellers and seasonal patterns of Kodiak Island waters. The spring phytoplankton bloom around Kodiak occurs in May, (R. Foy, University of Alaska Fairbanks; unpubl. data) bringing shortly after it a pulse of secondary production that is forage for many fish species (R. Foy, University of Alaska Fairbanks; unpubl. data). Late May is the time when male Stellers begin to arrive at the rookeries with the females following soon after (Gisiner 1985). The pups are born from late May to early July (Pitcher and Calkins 1981), coinciding with pulses of prey availability from forage fish such as herring and sandlance. Also by this time the previous year's pups are well developed or weaned (Trites and Larkin 1996). By early November the Stellers have left rookeries and dispersed to haulouts. Fish tend to be at their highest energy density just prior to winter (R. Foy, University of Alaska Fairbanks; unpubl. data). The largest biomass of fish also appear on the continental shelf during November (R. Foy, University of Alaska Fairbanks; unpubl. data). March is oceanic winter for the waters surrounding Kodiak Island, little primary or secondary productivity occurs and many fish species move offshore (R. Foy, University of Alaska Fairbanks; unpubl. data).

Diver visual transects:

Transects were conducted to quantify adult and juvenile fish abundance, algal community structure, and substrate composition. Each transect was in a direction that maintained a particular depth contour, roughly parallel to the shoreline. At each sampling depth, three 30 m transects were placed end to end, but separated by a randomly selected distance of at least 5 m.

Belt transects were used for the fish surveys as described by Brock (1954) modified by Quast (1968) and accepted by current kelp forest ecologists (Carr 1992, Levin 1991, 1993). On each of the 278 belt transects all benthic fish were identified and counted that were within 1 m of the bottom in a 4 m wide swath, 2 m on either side of the transect mid-line. All fish were counted that were swimming within visual range in front of the diver (Bodkin 1986). Pelagic fish were counted at approximately 5 to 10 m off the bottom, depending on visibility, directly over the benthic transects. All fish swimming at least 1 m or more above the bottom and within view in either direction were counted. Large schools were only noted on a presence/absence basis as individual fish were too numerous for an accurate count. Width of the pelagic transects was estimated as twice the visibility at 1 m off the bottom. Visibility was measured at the beginning of each sampling event. If initial bottom visibility was less than 3 meters, usually due to a phytoplankton bloom in the area, sampling for that area was postponed generally for no more than 1-3 days until visibility improved.

Precautions were taken to avoid sampling error during the fish transects. All divers for this study were trained in sampling protocol, as well as fish and algal identification. The trained diver responsible for the fish census remained in front of all other divers, and made every effort to sample an undisturbed fish population. This was done by maintaining constant speed (Lincoln-Smith 1988), limiting bottom contact and noise production. To ensure that cryptic species were detected, prostrate algal fronds were overturned and rock crevices were inspected. A possible bias associated with fish following divers was avoided by only counting fish in front of the diver on the transect line (Sale 1997). Ronquils, *Bathymasteridae,* as a group, retreated to crevices immediately upon sighting a diver, but have a body shape and swimming pattern that allowed them to be identified to family. Preliminary observations indicated that pelagic fish were relatively undisturbed by the presence of the divers on the benthic transects, and their activity returned to normal prior to the beginning of the pelagic counts.

Although the accuracy of visual fish census by divers has been debated, studies have found that when observers are trained, this method provides accurate and precise density estimates (Davis and Anderson 1989, Thompson and Mapstone 1997). This is the preferred method of most researchers for non-destructive counts of juvenile fish in reef habitats (Carr 1992, Levin 1991, 1993). Other traditional methods of fish census such as seining or gill-netting are not allowed in waters immediately adjacent to Steller haulouts, nor would they be

possible in the complex structure of kelp beds and bedrock outcrops at these headlands.

Algal and habitat methods:

While the fish surveys were being conducted by one diver, a second diver followed behind quantifying macroalgal cover and determining bottom substrate composition. This information was used to determine the similarity of habitat at each site and to address hypothesis 2. Kelp forest habitat description requires three different scales of measurement to accurately quantify the different layers of macroalgal cover; canopy, overstory and understory or turf algae. Swaths, quadrats, and random point contact measurements were used to sample these three different scales of habitat. All of these methods have been widely used to quantify macroalgae (Foster and Schiel 1985, Edwards 1998, Konar 2000). Along with macroalgae, the composition of the bottom substrate particle size was qualitatively characterized to determine its suitability for algal colonization.

Larger, adult, canopy forming bull kelp, *Nereocystis leutkeana*, which occurred along transects, exists in a much lower frequency than the overstory or understory macroalgae. Stipes of *N. leutkeana* were counted along the 30 m transect line in a 2 m wide (1 m on each side) swath.

Overstory kelp stipes and juvenile canopy kelps were counted and identified within a 0.25 m^2, three-sided quadrat sampling frame (Figure 4, modified from Coyer et al. 1999) randomly placed adjacent to the transect line. Four replicate quadrats were randomly sampled on each transect. The number

and species of kelp stipes were recorded. The percent cover of small understory red algae, geniculate coralline algae, and sessile invertebrates was also estimated within the 0.25 m^2 quadrats (Dethier et al. 1993).

Bottom substrate data were gathered using a 1 m long random point contact (RPC) bar (Figure 4, Cowen et al. 1982) that was attached to the 0.25 m^2 quadrat for the quantification of small algal species, sessile invertebrates, and substrate particle size composition. Following quadrat placement, the diver would observe and record five random contact points to the left of the bar, designated by knots in a string connected to the sampling frame. Any mobile invertebrates or algal fronds would be moved aside until the knot contacted primary substrate. The line would then be flipped to the right side of the bar and the process repeated.

Statistical methods:

All data were compiled in a database then analyzed and graphed using Statistica (StatSoft version 6.1) and Excel (Microsoft 2002). Prior to analysis, all data subsets were examined for normality and homogeneity of variances by graphical interpretation of residuals. Count data were $\log_{10}(x+1)$ transformed for non-normal data and then re-examined for normality and homogeneity of variance following transformation. Percent cover data were arcsine($\sqrt{x}$) transformed and re-examined (Zar 1996).

Because of heavy seas during the November sampling, we were unable to sample the Hanin Rocks, non-Steller haulout (control) site. Also, six of the 33 m

depth transects were also not sampled due to the physiological limitations of the SCUBA divers during the surveys (sample sizes are reported in Table A1). This resulted in an unbalanced design inappropriate for traditional Type III orthogonal sum-of-squares ANOVA (Nelder and Lane 1995). Effects were therefore ordered according to predicted effect, and Type I sequential sum-of-squares general linear models (GLMs), as recommended by Nelder and Lane (1995,) were estimated to test for significant difference between Steller haulouts and control, as well as seasonal difference and depth strata differences for fish and macroalgal cover. To simplify interpretation of the results, all GLMs were run using the same order and interaction of effects with a Type I sum-of-squares design. Significant results were further explored using a *post-hoc* Tukey test (Zar 1996) and graphical interpretation. All figures depict untransformed data.

The primary concern of this study was to detect true differences among the Steller haulouts and the headland areas used as controls. Although the between-site differences were not a focus of this study, I recognize that the different sites had an impact on the total variability within the fixed effect factor (Steller haulout). Site, which was not assigned to the Steller haulout categories at random, is therefore included as a blocking factor, nested within the Steller haulout fixed effect factor.

Fish species were grouped for analyses (Table 1), both because the level of discrimination possible from the scats of the Stellers from Long Island and Cape Chiniak suggested particular family groupings and because some

individual taxa were too rare to analyze individually. Schooling fish were accounted for on a presence or absence basis, since the large numbers of individuals in these schools were impossible to quantify accurately. Presence or absence of these schooling fish was compared as in Dean et al. (2000). A Kolmogorov-Smirnov test was used to assess the hypothesis that there was no difference in the proportion of sites with schools at Steller haulouts from control sites.

To examine diversity, a count of the total number of fish species seen on a transect was used (Bodkin 1986). The type I sum-of-squares was estimated with a GLM, using the same order and interaction of effects as in the estimation of abundances. Due to the large number of zeros in the data set, typical for this type of transect work, Shannon Weiner and other diversity indices were inappropriate. While a count of species present only measures species richness, not evenness, it allowed a measure of diversity comparison between the Steller haulout and non-haulout sites.

Substrate data were grouped for analysis as unstable, stable, benthic sessile invertebrate cover, or turf algae. Unstable substrate consisted of sand, gravel, and shell hash. Stable substrate was bedrock, boulders, and non-geniculate coralline algae. Sessile benthic invertebrates were barnacles, hydrozoa, bryozoa, anemone and tunicates. Turf algae included *Desmerestia ligulata,* a brown alga, and foliose red and green algae.

A Bray-Curtis dissimilarities matrix was created and analyzed with cluster analysis to expose patterns among sampling depths between Steller haulout and control sites (Dean et al. 2000). Bray-Curtis dissimilarity matrixes were calculated on abundance data on 21 species of fish, that were grouped by sampling depth and Steller and Control sites, then ln (x + 1) transformed. The algal habitat matrix was created with 16 different variables including species of macroalgae and functional groups such as foliose red and green algae. Substrate data consisted of 23 variables including species level identification of invertebrates, and the five categories of substrate: shell hash, sand, gravel, non-geniculate coralline algae, and bedrock. Cluster analysis on each of the three dissimilarity matrices was then performed to allow comparison between the different levels of data in transects, quadrats and RPC measurements.

Results:

During the five sampling periods of July 2001 through July 2002, fish fauna varied across sampling periods and sampling depths as well as between control and Steller haulout sites in total abundance and species richness. Trends were investigated for each analysis group as well as for the total fish abundance and species richness. Overall, 956 individual fish of 21 species were observed on 188 of the 278 benthic transects surveyed over the five sampling periods (Table 2). Kelp greenling, *Hexagrammos decagrammus,* black rockfish, *Sebastes ciliatus*, ronquils, Bathymasteridae, and red and yellow Irish lords, *Hemilepidotus*

spp., were the most abundant species, with the highest frequency of occurrence (Table 2).

Abundance of all fish:

While both Steller and control sites showed significant fluctuation patterns in fish abundance with sampling periods and depth, mean fish abundance between Steller and control sites was significantly different [$F(1, 185) = 8.52$, $p = <0.01$; Figure 5; Table A2]when the mean number of fish per 120 m2 transect were compared across all sampling periods and depths combined. During the July 2001 sampling period the control sites showed a significantly greater mean abundance of fish at the sampling depths of 15, 21 and 27 m than was found at the Steller haulout depths during the same period. Overall, the total abundance of all fish was higher during the summer sampling periods of July 2001 and July 2002 with a concentration of fish in the mid sampling depths of 15 m and 21 m. November, March and May showed a lower, but more even, distribution of fish abundance across all sampling depths. *Post hoc* tests showed no significant differences in abundance between the November 2001, and the March and May 2002 sampling periods.

Fish species richness:

Fish species richness was not significantly different between Steller and control sites when data across all sampling periods and depths were combined [$F(1, 185) = 2.14$, $p = 0.15$; Table A5]. However, significantly greater numbers of fish species were present during the summer sampling periods, and at the

shallow depths of 9, 15, and 21 meters [F(16, 185) =10.92, p=<0.01; Figure 6, Table A5]. While the deeper depths of 27 and 33 meters had lower relative species richness during the summer months than the other depths, the number of species present at these deeper depths increased slightly during the winter and spring sampling periods of November, March and May. This resulted in no significant difference in species richness between the sampling depths during these sampling periods.

Fish analysis groups:

The greenling analysis group, which was primarily dominated by kelp greenling, significantly differed in mean abundance between Steller and control sites, as well as showing significant depth and seasonal differences (Figure, 7, Table A6). The greenling analysis group had an even spatial distribution of individuals; most sightings were of a single fish, or infrequent groups of 2 or 3 fish. The greenling were significantly more abundant at the Steller haulouts with a mean abundance of 1.4 +/- 0.2 fish per 120 m^2 at haulouts and only 0.7 +/- 0.1 fish per 120 m^2 at control sites (Table 3) [F(1,185) =17.63, p=<0.01; Table A6]. There was also a significant difference in greenling abundance among depths, with a higher abundance in the shallow depths [F(4,185) =19.04, p=<0.01; Figure 7, Table A6]. This difference in depth distribution of greenling was most apparent during the summer sampling events of July 2001 and 2002, when there was a significantly greater number of greenling seen at 9, 15 and 21 m [F(4, 185)=3.53, p=0.01; Table A6].

Rockfish, although encountered on only 53 transects, were the most abundant analysis group, and differed significantly in abundance between Steller and control sites, and among both sampling periods and depths (Figure 8, Table A7). Ninety-six percent of the rockfish seen were black rockfish, *Sebastes ciliatus,* which were occasionally encountered in large groups. As an analysis group, the rockfish were significantly less abundant at Steller haulout sites than at control sites, 0.6 +/- 0.3 and 3.2 +/- 0.7 fish per 120 m^2 respectively [F(1,185) =55.48, p=<0.01; Table 3, Table A7]. During the July 2001 and 2002 sampling periods, significantly greater numbers of rockfish were encountered, [F(4, 185) =23.28, p=<0.01; Table A7] at the 21 and 27 m sampling depths [F(4, 185) = 9.71, p=<0.01, Table A7].

Yellow Irish lords, *Hemilepidotus jordani*, and red Irish lords, *Hemilepidotus hemilepidotus*, accounted for 80% of sculpins encountered. As a group, sculpin abundance was significantly different among sampling periods, [F(4,185)=3.59, p=0.01; Appendix 6] and among depths, [F(4,185)=3.74, p=0.01; Appendix 6]. Sculpins did not significantly differ in abundance between the Steller haulout and control sites, with both having a mean of 0.3 +/- 0.1 fish encountered per 120 m^2 transect, [F(1,185)=0.08, p=.78; Figure 9, Table 3, Appendix 6).

The analysis of ronquil abundance showed significant differences on all sampling levels: seasonally, sampling depths and between Steller haulout and control sites (Figure 10, Table A9). Ronquil abundance was significantly greater during the July 2001 and 2002 sampling events, [F(4,185)=10.87, p=<0.01; Table

A9]. Ronquils were most commonly found at the depths of 15, 21 and 27 meters, [F(4,185)=2.77, p=<0.03; Table A9]. There was a small, but significantly lower mean abundance of ronquils at Steller sites than at control sites, 0.1 +/- 0.1 versus 0.2 +/- 0.1 fish per transect respectively [F(1, 185)=8.06, p=0.01; Table 3, Table A9].

The flatfish, which were primarily rock sole, *Lepidopsetta* spp., showed significant differences in mean abundance among sampling periods and depths, but not between Steller haulout and control sites (Figure 11). Flatfish were only seen at the two deepest sampling depths of 27 m and 33 m [F(4,185)=6.54, p=<0.01; Table A10]. Flatfish were at both Steller and control sites with means of 0.1 fish +/- 0.0 per 120 m^2 transect [F(1,185) =1.34, p=0.25; Table 3]. There was a significantly greater abundance of flatfish during the March and May 2002 sampling periods [F(4,185) =3.19, p=0.01, Table A10].

The rare fish analysis group combined the remaining fish seen that did not group with the others taxonomically. The tubesnout, *Aulorhynchus flavidus,* which was seen on three occasions, was the only rare species to be encountered on more than one transect. No significant difference was found in the abundance of rare fish among sampling depths [F(4,185) =0.59, p=0.7; Table A11] or between the Steller haulout and control sites [F(1,185) =0.09, p=0.8; Table A11]. Rare species were only encountered during the July 2001, May 2002 and July 2002 sampling periods, resulting in significant sample period differences [F(4,185)=2.48, p=0.05; Figure 12, Table A11].

Most fish observed during the pelagic counts were schooling fish, particularly Pacific sandlance and young-of-the-year gadids, believed to be Pacific cod. Schooling fish were encountered on a total of 15 transects (Table 4). The only other fish seen on pelagic transects were black rockfish, in groups of 9, 13, 6, 1, 1, and 4 and a single rock greenling. These seven instances of pelagic sightings out of 278 transects were too rare to analyze successfully, and their presence is simply noted. All but two of the transects with schooling fish were at Steller haulout sites, predominately during the July 2001 sampling period.

Canopy kelp:

The only species of canopy-forming kelp found at the study sites, *Nereocystis leutkeana* commonly called bull kelp, was limited to the 9 and 15 m depths. There was no significant difference in the density of bull kelp between Steller and control sites [$F(1,185)=0.00$, $p=0.96$; Table A12]. *Nereocystis leutkeana* density was significantly different between sampling dates because of a large recruitment event that was seen in March and May 2002 [$F(4, 185)=12.97$, $p=<0.01$; Figure 13].

Overstory kelp:

The total abundance of all overstory combined kelp stipes was significantly different among sampling depths [$F(4, 1005) =907.15$, $p=<0.01$; Figure 14, Table A13]. These kelp stipes were most dense at 9 m depth, with a combined mean density of 16.7 +/- 1.7 stipes per 0.25 m^2. The abundance of all kelp species rapidly dropped off with depth, until, at 21 m the mean density was

2.4 +/- 0.2 stipes per 0.25 m^2. *Post-hoc* Tukey results on the stipe-count depth differences indicate that only the 27 and 33 m sampling depths were similar in the density of macroalgal cover (Table 5). All other depths showed significant differences in the density of overstory kelp stipes, with the greatest density occurring in the shallow 9 m depth and decreasing significantly with each increasing sampling depth down to 27 m. No significant difference was found between Steller and control sites in total overstory stipe density, [$F(1, 1005) = 0.02$, $p=0.88$], or among sampling periods [$F(4, 1005) = 0.97$, $p=0.42$; Table A13].

There were notable differences in the depth distribution of the overstory kelp species (Figure 15). Both juveniles and adults of *Laminaria* spp., dominated at the 9 m sampling depth. Abundance of *Laminaria* spp. declined until 21 m, when it approximated that of *Agarum clathratum* at about 1 stipe per 0.25 m^2. At 27 meters, few individuals very found. No overstory kelp stipes were encountered at 33 meters depth.

Turf algae and substrate:

Although the sample size was as large as logistically possible, 34 out of 36 levels tested with the established GLM procedure resulted in significant results for the analysis groups: stable substrate, unstable substrate, turf algae, and benthic invertebrate cover (Tables A14-A17). This suggests that the environment was too variable on this scale for the sample size, even with the

combination of the data into substrate groups. Therefore results are presented graphically in Figure 16, and general trends are discussed.

Unstable substrate was most commonly found at the depths of 27 and 33 m, where it constituted between 50 and 100% of the substrate (Figure 16). Very little unstable substrate was found at 9, 15 and 21 m. Substrate at these sampling depths was approximately 50% stable substrate and 40% sessile invertebrate cover. The remaining 10% cover was unstable substrate, (in patches in the surge channels), or turf algae.

Multivariate cluster analysis:

Multivariate cluster analysis of the fish distribution showed two major separations in the pattern of dissimilarity between the sampling depths at Steller haulout and control sites (Figure 17). First, to separate out at a linkage distance of 82%, were the 33 m sampling depths at both Steller haulout and control. At a linkage distance of 58%, the Steller haulout depths of 9, 15 and 21 m separated from Steller 27 m, and Control 9, 15, 21 and 27 meters.

Canopy, overstory and turf macroalgal habitat separated into depth patterns irrespective of Steller and control grouping (Figure 18). The control sampling depth of 33 meters separated first at nearly 100% distance from all other sample units. It was, however, most similar to the Steller haulout 33 meter sampling depth, which next separated out at a linkage distance of approximately 70%. The other sampling units were very similar, with breaks in similarity occurring between linkage distances of 10 and 22%. Each Steller haulout

sampling depth was more similar to its control counterpart than to any other sampling unit.

Cluster analysis of the substrate indicated that all sampling depths, at both control and Steller haulout sites, were very similar (Figure 19). The first separation for the control 33 m sampling unit was at a 40% linkage distance, less than half the linkage distance of the first separation in the fish and macroalgal habitat analyses. The results for substrate then broke into two units; the Steller haulout deep depths of 27 and 33 m and the control 27 m, and the 21, 15 and 9 m for both control and Steller sites. Notably, the Steller haulout sampling depths of 21, 15 and 9 m then formed a sub-group that broke off at a linkage distance of 20%, resembling the distinctions in the fish cluster analysis.

Discussion:

The nearshore subtidal environment around Steller haulouts examined in this thesis is home to a diverse fish fauna and algal habitat. Young-of-the-year and weaning Stellers supplement their mother's milk and learn to forage in these nearshore areas. The purpose of this study was to document the fish fauna and habitat of these nearshore areas to determine if differences existed between sites used and not used as haulouts by Stellers.

This study found that the nearshore kelp habitat, both canopy and overstory, of Steller haulout sites is not significantly different from other headland areas in Chiniak Bay, Alaska. Both Steller haulout and control sites had a seasonal cover of the canopy forming kelp, *Nereocystis leutkeana* during the

summer months. There was heavy overstory algal cover, primarily of the order Laminariales, down to a depth of 21 meters at both the Steller haulout and control sites. The algal species composition and abundance from sites in this study are similar to those found by Calvin and Ellis (1978) at sites off Kodiak Island's outer coast. They are also similar to exposed sites in Prince William Sound and in Southeast Alaska (Dean et al. 2000, Murphy et al. 2000).

Both Steller haulout and control sites abruptly transitioned from bedrock substrate with algal cover to gravel and shell hash between 21 and 27 meters. This transition line, which varied slightly in depth depending on the location of surge channels, marked the lower limit of algal distribution and the beginning of the sand and gravel substrate. Although Steller haulouts were not significantly different from other headland areas in this respect, the habitat complexity in the kelp beds down to 21 m may be training grounds for young Stellers learning to detect and pursue prey in a structurally complex environment. Likewise the bare sand and gravel substrate at the 27 and 33 m depths may offer another environment to develop foraging skills. Although the flatfish such as the rock sole that were found in the 27 and 33 m depths have no structural protection, these fish do have highly developed cryptic coloration. Many of the fish found in both of these habitats, including greenling, Irish lord, soles and rockfish, are found in Steller scats at Long Island and Cape Chiniak (Wynne et al. 2003).

I reject both null hypotheses addressed statistically in this study.

- H_O: There is no statistically significant difference between the fish fauna at Steller haulout and non-haulout sites.
- H_O: Difference in the fish populations between Steller and non Steller haulout sites cannot be explained by corresponding differences in the habitat as described by macroalgal cover, substrate, and benthic invertebrate fauna.

Even though Steller haulout and control sites had similar algal cover and substrate type, fish assemblages between sites were statistically different.

A relatively lower abundance of rockfish and a higher abundance of greenling were found at the Steller haulout sites. Also, while ronquil abundance was very low at both Steller haulout and control sites, significantly fewer ronquil were found at Steller sites. Although ronquils are found in Steller scats from Long Island and Cape Chiniak (Wynne et al. 2003), it is unknown whether the statistical differences in the fish abundance indicate a true biological difference that could affect the foraging efforts of young-of-the-year and weaning Stellers.

Although many studies have found correlations between type of algal cover and fish abundance, algal cover did not appear to be related to the observed differences in fish abundance between Steller haulout and control sites. The substrate and fish cluster analysis had a similar grouping at the Steller haulout sampling depths of 9, 15 and 21m, perhaps indicating a possible relationship. Rugosity, which includes different size and number of rocks and types of bottom composition, has been found to account for a large part of the

spatial variability of reef fish (Garcia-Charton and Perez-Ruzafa 2001). Also, Friedlander and Parish (1998) specifically found that the size and number of holes in the substratum, such as small caves and crevasses, is a determining factor in abundance and size of fish on a reef. Luckhurst and Luckhurst (1978), however, found fish species richness was not correlated to substrate variability. These studies indicate that in order to understand the fish distributions that were seen in my study, rugosity should be considered as an important factor. Future studies of fish distributions in this area should include a measure of substrate complexity such as rugosity to test this relationship further.

Alternate hypothesis for the differences in fish abundance at Steller haulout and control sites are 1) prey depletion by the Stellers, or 2) a difference in fish behaviors caused by the presence of the Stellers at haulout sites. Both explanations, while interesting to consider, are beyond the scope of this project. Although numerous studies and theories exist on the depletion of prey due to foraging activity (reviewed by Dolman and Sutherland 1997), no studies document localized depletion of fish by a marine mammal predator. Similarly, while immediate predator avoidance behavior is well known for fish, I was unable to find evidence of long term "learned patterns" such as avoiding locations of predator concentration.

Although there were only slight differences in the fish fauna between Steller haulouts and control sites, the observed seasonal trends in nearshore fish abundance may be biologically significant to young-of-the-year Steller sea lion

foraging activity. Fish abundance was greatest in the nearshore areas during the July and November 2001 and July 2002 sampling periods. However, the depth of peak abundance shifted from the shallow water in July to deeper water during the November 2001, March and May 2002 samplings. This shift in the depth distribution might be explained by a behavioral response of the fish to large waves during November 2001. Bodkin et al. (1987) found instances of nearshore fish mortality associated with the large oceanic waves impacting the California shore during the 1987 El Nino event. In Kachemak Bay, Alaska, fewer fish were found in shallow nearshore kelp beds during the winter of 2002, perhaps indicating a seasonal deeper distribution of fish (J. Hamilton, University of Alaska, Fairbanks, unpubl. data). The lower fish abundance at 9, 15 and 21 m during the winter months was observed at both Steller haulout and non haulout sites. Dive studies suggest that these depths are foraging territory for young-of-the-year and weaning Stellers (Merrick and Loughlin 1997, Loughlin et al. 2003, Rehburg and Burns unpubl. data).

The seasonal pulses of forage fish, such as the sandlance schools encountered near the haulouts, also probably play an important role in the nutritional status of both the breeding and lactating females and the weaning Stellers (Sinclair and Zepplin 2002). Capelin, herring, and sandlance, are all found seasonally in the scats of Stellers from Cape Chiniak and Long Island haulouts (Wynne et al. 2003). These forage fish are all high in lipid content, and

congregate in dense schools in the early spring and summer months for spawning activity (Robards et al. 1999).

The hypothesis that nutritional stress, due to a decline in prey abundance caused by fisheries or by natural changes in the ecosystem, caused the Steller population decline in the 1970's and 1980's, is still is being investigated, however, it is not currently the most probable explanation for the initial precipitous decline (Springer 1998, DeMaster and Atkinson 2002, Benson and Trites 2002, NRC 2003, Springer et al. 2003). A combination of influences may be preventing the population from recovering, including predation, fishing gear interactions and pollution or disease (DeMaster and Atkinson 2002, NRC 2003). However, nutritional stress may be contributing to causes of mortality by increasing susceptibility to predation or disease. Captive Stellers, perhaps due to an increased amount of activity and lower seasonal energy density of food, required 45-60% more food per day during the period of December to February than during warmer months (Winship et al. 2002, Winship and Trites 2003). The results from this study imply that fish densities are much lower particularly at the depths of 9, 15, and 21 m, during the winter months, when weaning and young-of-the-year Stellers tend to be at the haulouts.

Foraging effort was observed to increase for captive Stellers kept on a restricted diet, which may be a behavioral response to under-nutrition (Rosen and Trites 2002). Lower seasonal abundance and quality of prey could theoretically translate into longer or more intensive foraging activity. A seasonal

increase in foraging activity for the adults may be detrimental to the weaning Stellers. Female Stellers spend a greater amount of time at sea between suckling bouts during the winter months of January to April, returning to the haulouts every three to eight days to suckle and rest (Merrick and Loughlin 1997, Trites and Porter 2002). During summer, females caring for pups averaged one foraging trip every 0.8-1.9 days (Millette 1999). This greater time interval between nursing bouts could have harmful effects to the weaning Stellers particularly since it appears that fish density significantly decreases during these months. Young Stellers, incapable of traveling far offshore for fish, probably use these low-density nearshore fish to supplement their diet. At six weeks of age Steller pups revert to protein catabolism within only 2.5 d of fasting (Rea et al. 2000). Although physiological resources would have increased by December when weaning Stellers are approximately 6 months of age, the decrease in fish prey at 9 and 15m where the weaning Stellers are foraging may be problematic. Attempts to forage in a lower prey density area to supplement the mother's milk, may result in higher energy expenditures with little reward. Young-of-the-year Stellers, without the added nutrition that the weaning Stellers receive from mother's milk, may be particularly vulnerable to the seasonal effects of under-nutrition due to the lower abundance of fish during winter months as seen in the November 2001, March and May 2002 sampling.

This study has demonstrated that although algal cover was similar between Steller and control sites in Chiniak Bay, statistically significant

differences in the abundance of ronquil, greenling and rockfish were found. While these differences may be partially attributed to substrate variability or to the effects of the numbers of Stellers at haulouts, it is doubtful whether the differences observed in the fish fauna explain why some headland areas are used as Steller sea lion haulouts and other headlands are not. Perhaps other factors such as deep water near the haulouts, (necessary for quick re-entry), a sloping exit/entry point for the pups, or proximity to offshore feeding areas for the females account for haulout use patterns. Also of note is the observed lower fish abundance during November 2001, March and May 2002. This lower fish abundance is particularly apparent at the depths of 9, 15 and 21 m, which appears to be prime foraging territory for young-of-the-year and weaning Stellers.

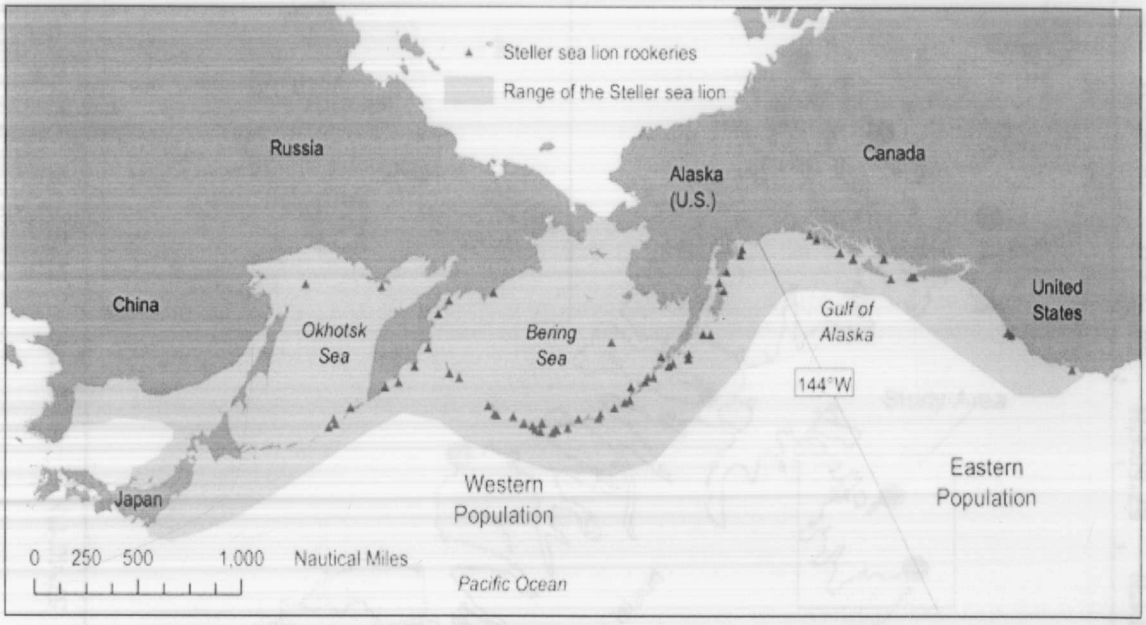

Figure 1: Map showing Steller sea lion range. Steller sea lions are distributed around the North Pacific Ocean rim from the Channel Islands to Japan (shaded area). Rookeries are shown as triangles. The population is divided into an Eastern and Western stock at 144 ° W longitude. Map: NOAA, Alaska Fisheries Science center. http://www.afsc.noaa.gov/Stellers/range.htm

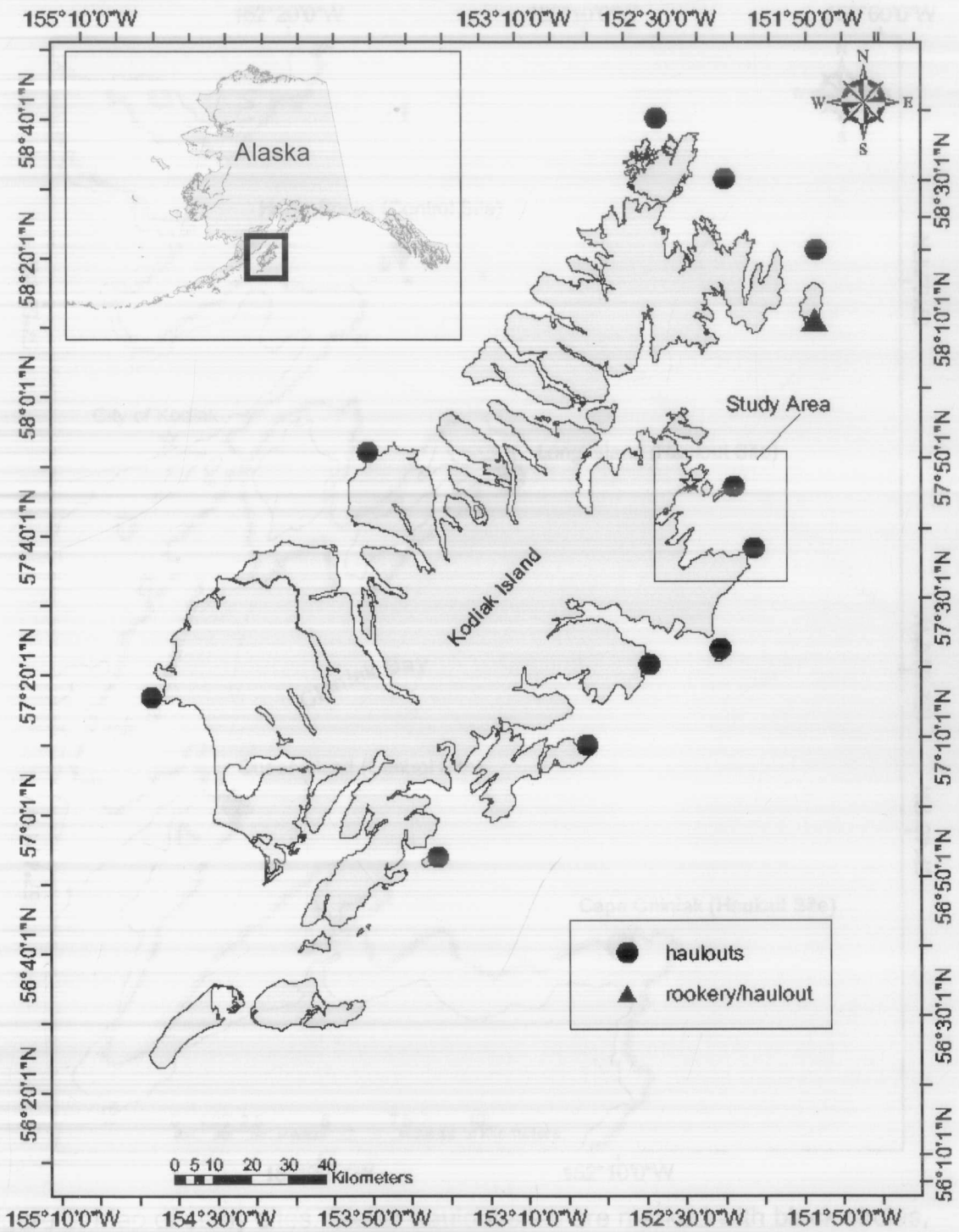

Figure 2: Kodiak Island Steller sea lion haulouts and rookery. Haulouts shown with black circles and the only rookery, Marmot Island, with the black triangle. Inset box indicates location of study area: see Figure 3.

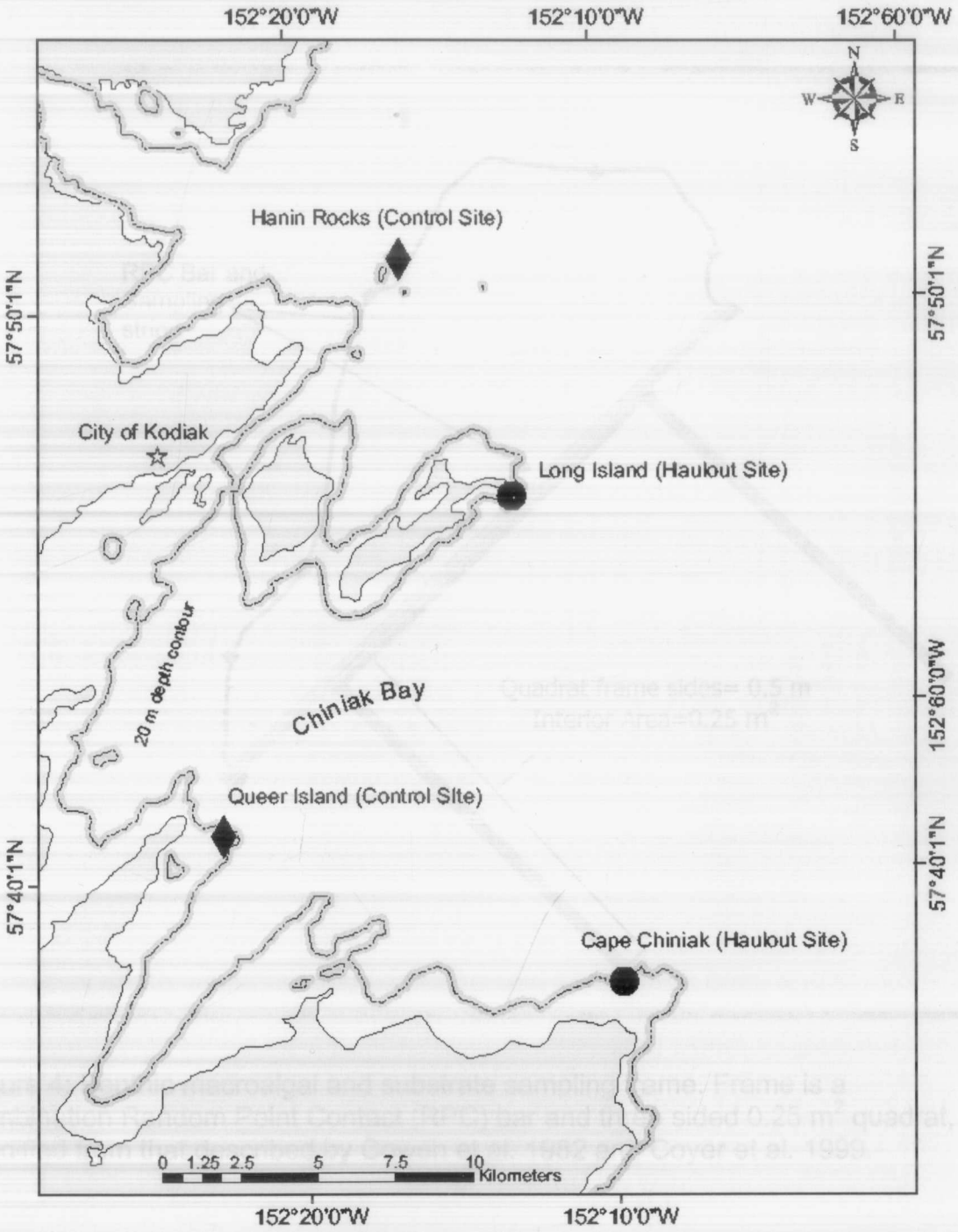

Figure 3: Map of study sites. Steller haulout sites are marked with black circles, control sites with black diamonds. Shaded line indicates the twenty meter depth contour. This marks the approximate outer edge of kelp habitat and beginning of sand and gravel bottom at the study sites.

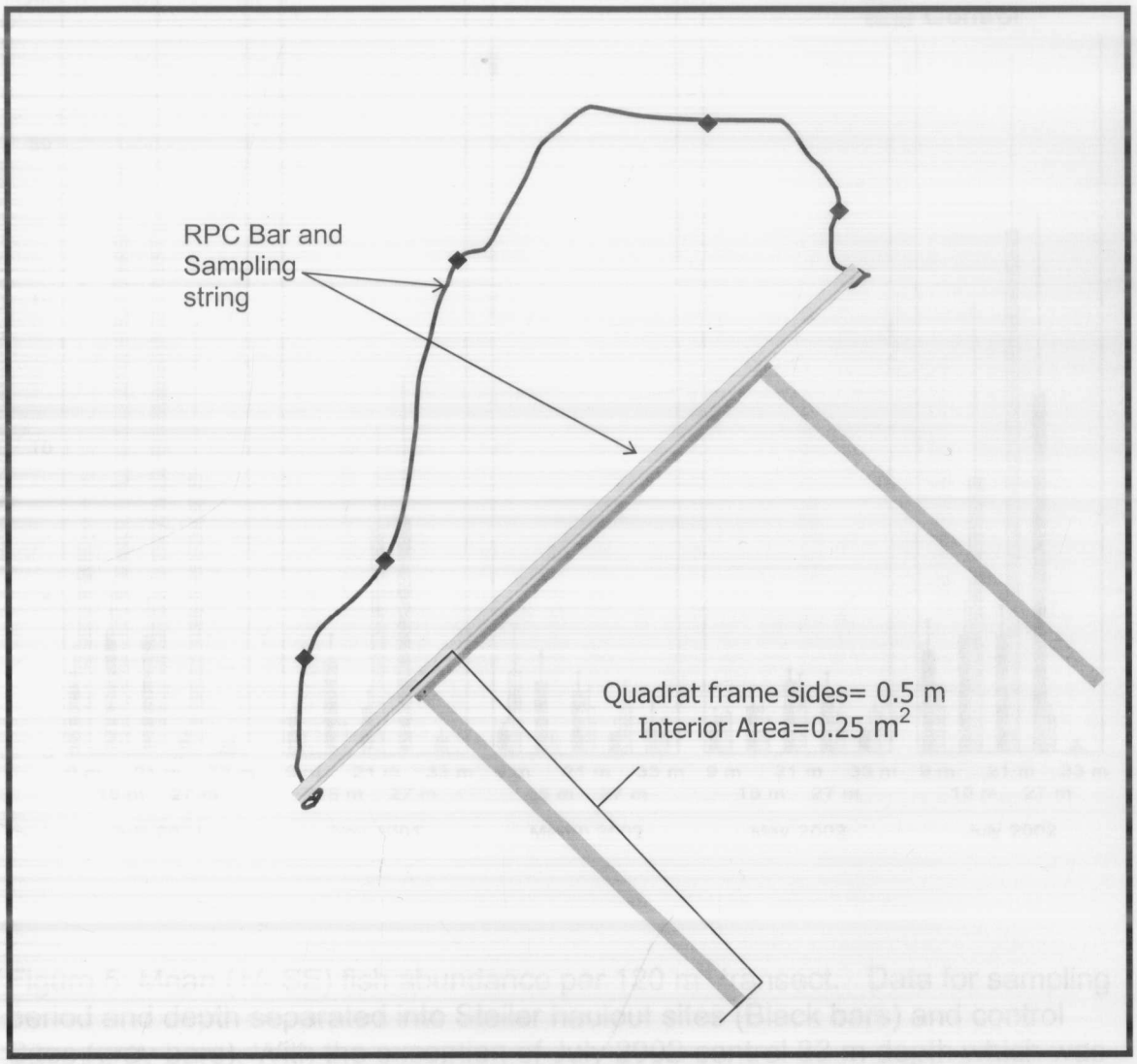

Figure 4: Benthic macroalgal and substrate sampling frame. Frame is a combination Random Point Contact (RPC) bar and three sided 0.25 m^2 quadrat, modified from that described by Cowen et al. 1982 and Coyer et al. 1999.

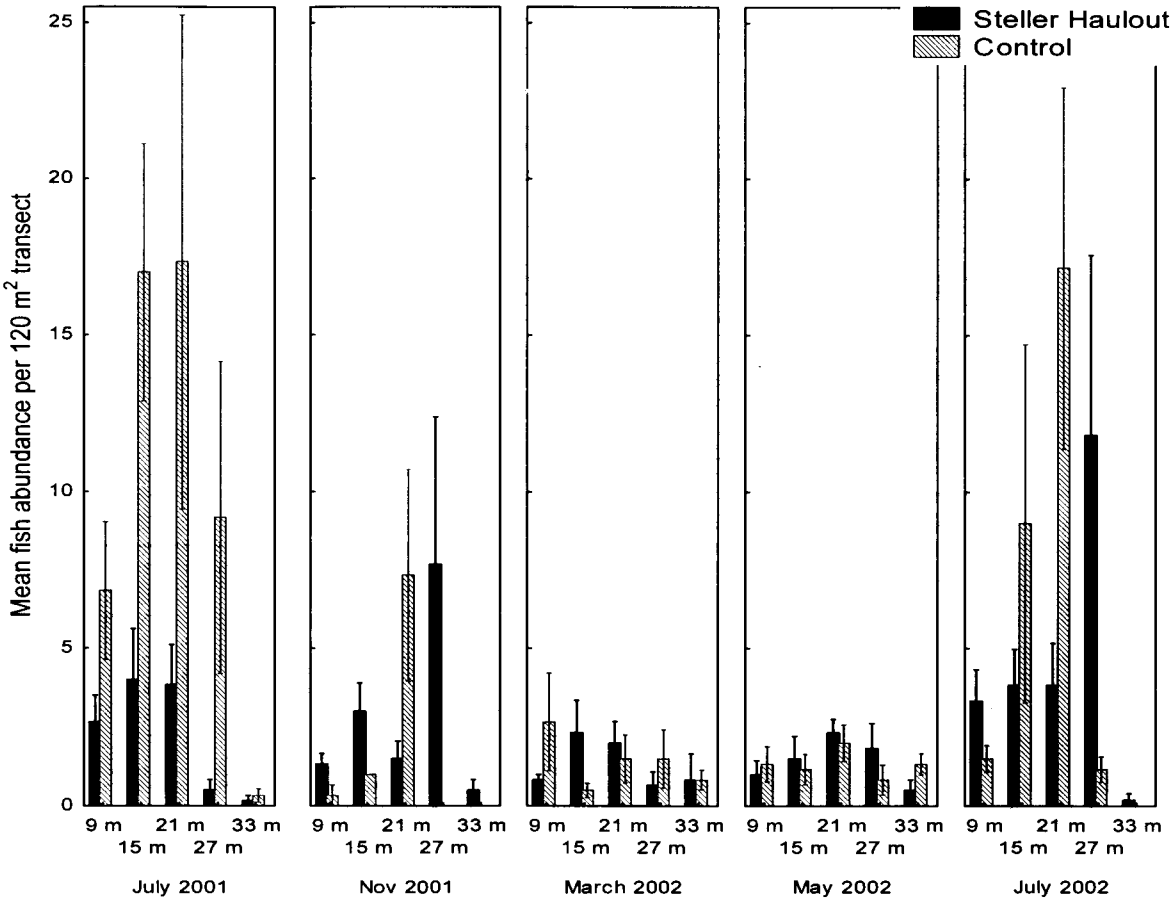

Figure 5: Mean (+/- SE) fish abundance per 120 m^2 transect. Data for sampling period and depth separated into Steller haulout sites (Black bars) and control Sites (gray bars). With the exception of July 2002-control 33 m depth which was unsampled, zero values exist (no fish seen on transects) where no bars are shown. Steller haulout and control sites are significantly different, when data across all sampling periods and depths were combined [$F(2,185) = 8.52$, $p = <0.01$]. There is a significant difference between sampling periods: [$F(4,185) = 20.59$, $p = <0.01$], and between sampling depths [$F(4,185) = 25.13$, $p = <0.01$] [Tables A2-A4].

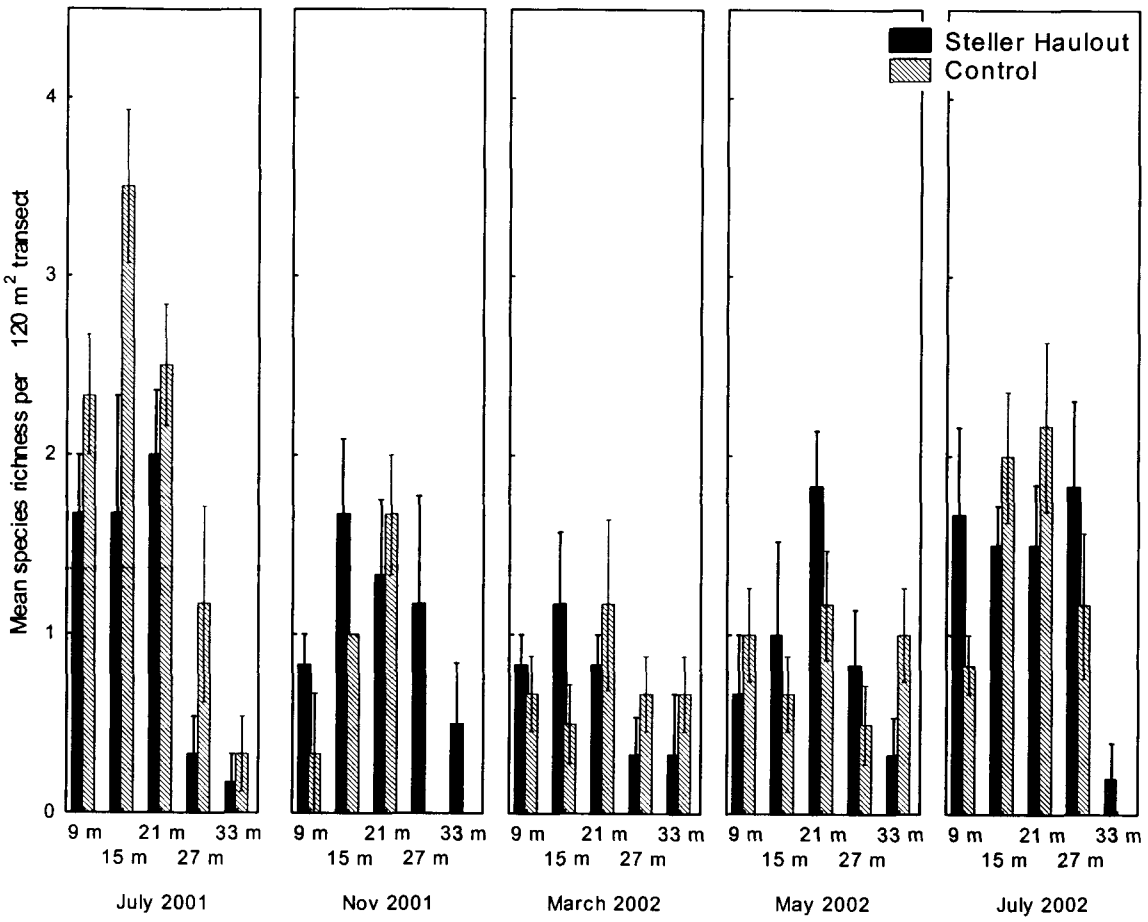

Figure 6: Mean (+/- SE) species richness per 120 m^2 transect. Data for sampling period and depth separated into Steller haulout sites (Black bars) and control sites (gray bars). With the exception of July 2002-control 33 m depth which was unsampled; where no bars are shown, zero values exist (no fish seen on transects) for that data point. There is no significant difference between Steller and control sites [F (1, 185) =2.14, p=0.15], but a significant difference exists between sample periods [F(4,185) =10.92, p=<0.01], and between depths [F(4,185)=24.14, p=<0.01] [Table A5].

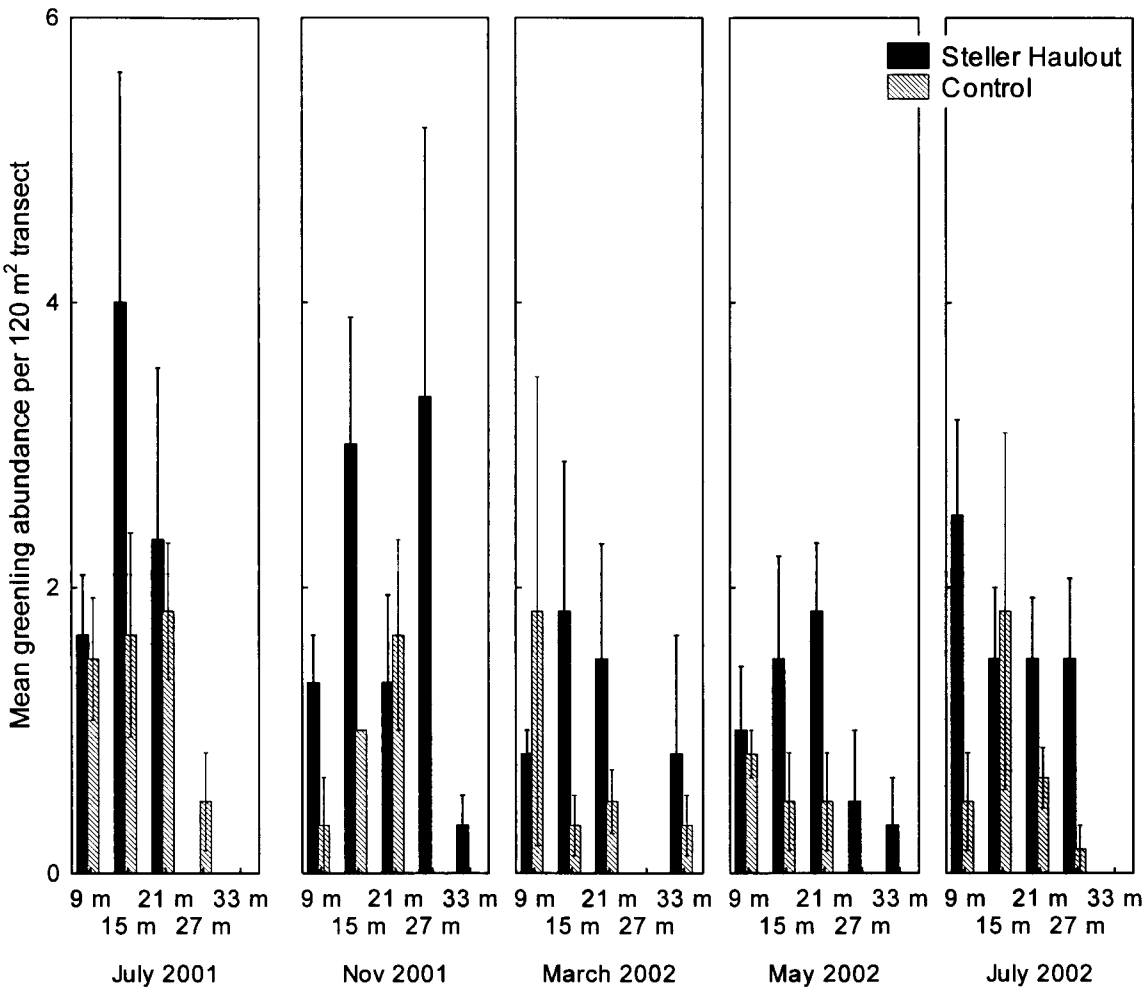

Figure 7: Mean (+/- SE) greenling abundance per 120 m^2 transect. Data for depth and sampling date separated into Steller and control sites. Black bars indicate Steller haulout sites. Grey bars are control sites. With the exception of July 2002-control 33 m depth which was unsampled, zero values exist (no fish seen on transects) where no bars are shown. There was a significantly higher abundance of greenling at Steller sites than at control sites [$F(2,185) = 17.63$, $p = <0.01$]. There was also a significant difference between sampling periods [$F(4,185) = 3.53$, $p = 0.01$], and between depths [$F(4,185) = 19.04$, $p = <0.01$] [Table A6].

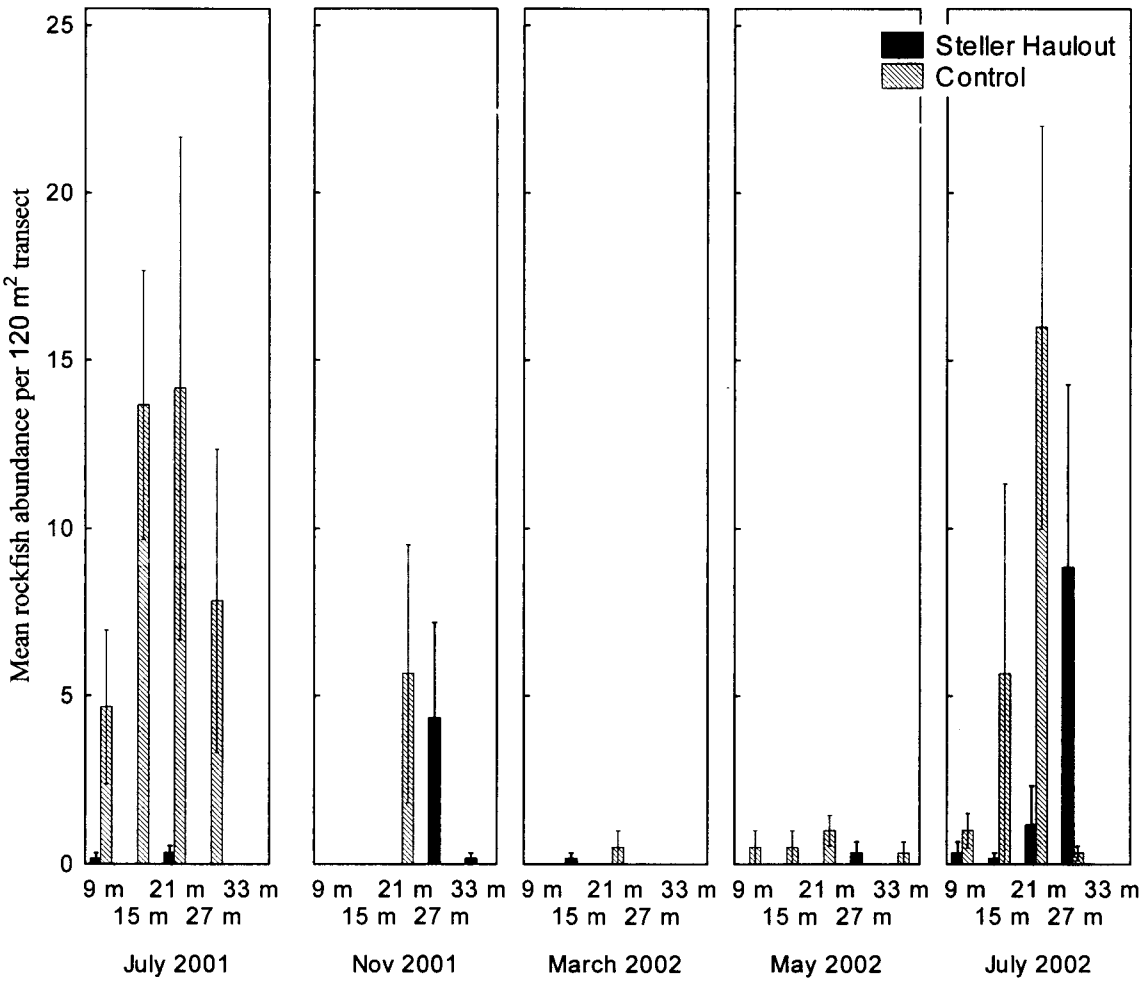

Figure 8: Mean (+/- SE) rockfish abundance per 120 m^2 transect. Data for depth and sampling date separated into Steller and control sites. Black bars indicate Steller haulout sites. Grey bars are control sites. With the exception of July 2002-control 33 m depth which was unsampled, where no bars are shown, zero values exist (no fish seen on transects) for that data point. There was a significant difference between Steller haulout and control sites: $F(4,185) = 55.48$, $p = <0.01$, sampling periods: $F(4,185) = 23.28$, $p = <0.01$, and depths: $F(4,185) = 9.71$, $p = <0.01$] [Table A7].

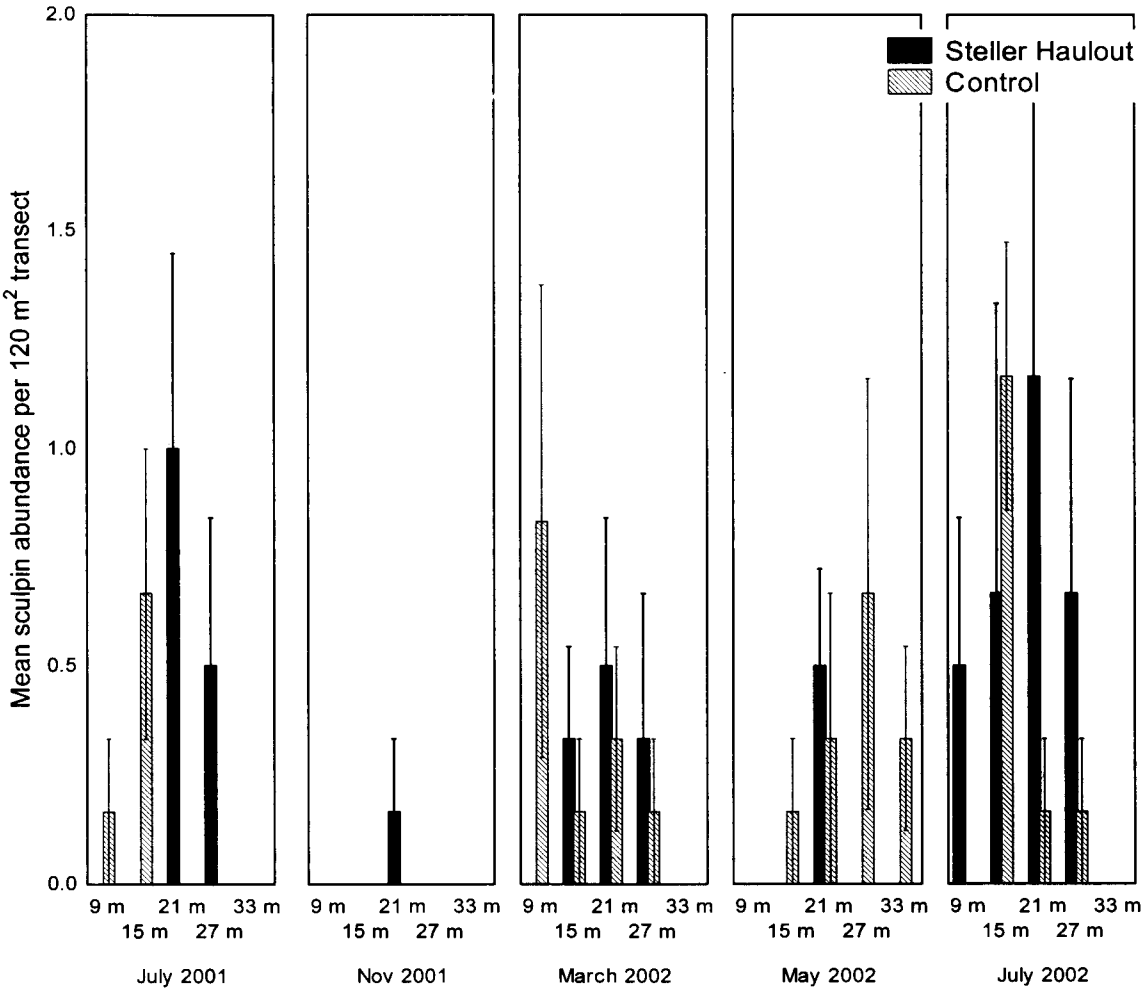

Figure 9: Mean (+/- SE) sculpin abundance per 120 m^2 transect. Data for depth and sampling date separated into Steller and control sites. Black bars indicate Steller haulout sites. Grey bars are control sites. With the exception of July 2002-control 33 m depth which was unsampled, where no bars are shown, zero values exist (no fish seen on transects) for that data point. There was no significant difference between Steller haulouts and control sites [$F(4,185)=0.08$, $p=0.78$]. Significant differences existed between sampling periods [$F(4,185)=3.59$, $p=0.01$], and depths [$F(4,185)=3.74$, $p=0.01$] [Table A8].

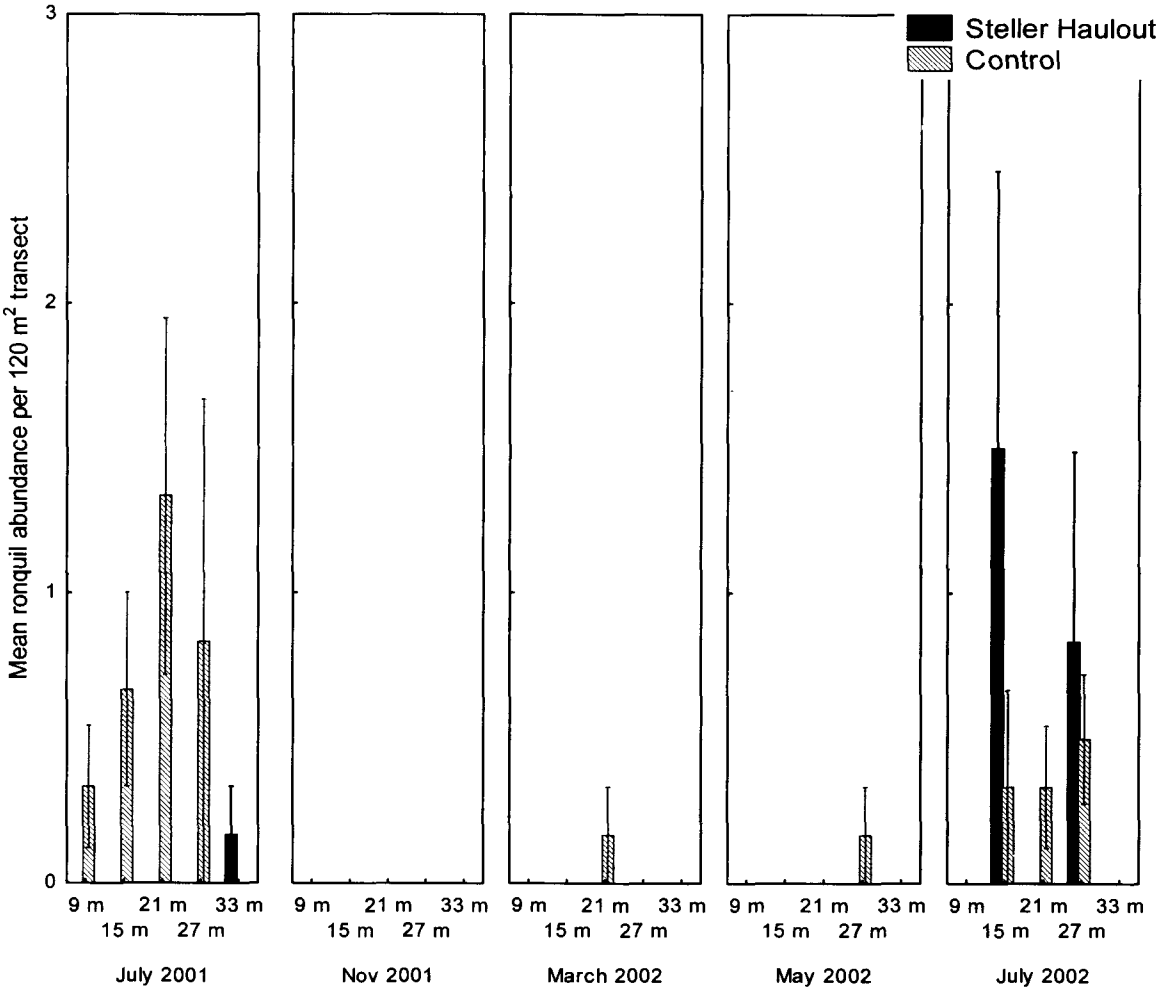

Figure 10: Mean (+/- SE) ronquil abundance per 120 m^2 transect. Data for depth and sampling date separated into Steller and control sites. Black bars indicate Steller haulout sites. Grey bars are control sites. With the exception of July 2002-control 33 m depth which was unsampled, zero values exist (no fish seen on transects) where no bars are shown. There were significantly less ronquil at Steller haulouts than at control sites [$F(1,185) = 8.06$, $p=0.01$]. There were also significant differences between sampling periods: [$F(4,185) = 10.87$, $p=<0.01$], and depths [$F(4,185) = 2.77$, $p=0.03$] [Table A9].

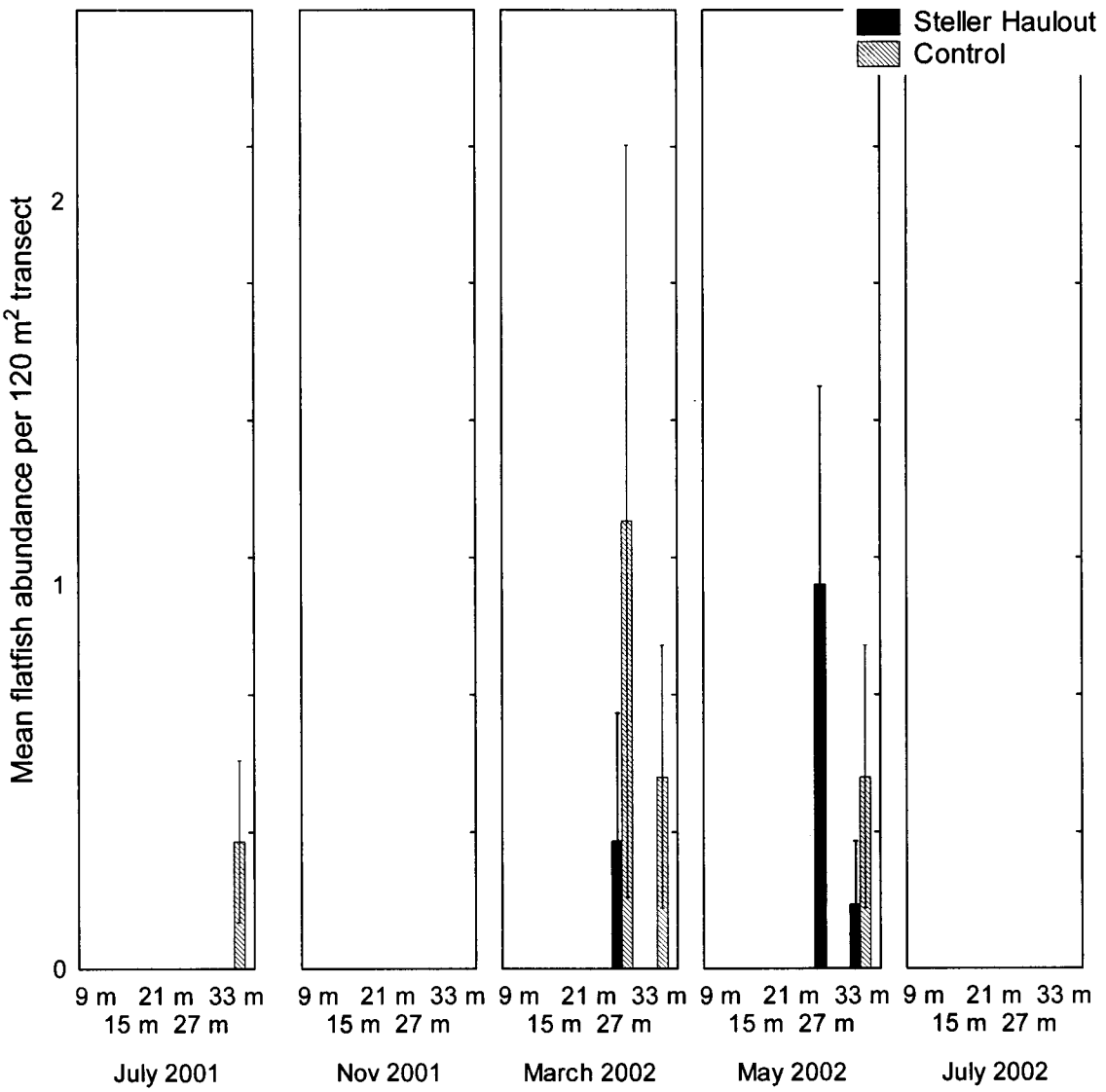

Figure 11: Mean(+/- SE) flatfish abundance per 120 m^2 transect. Data for depth and sampling date separated into Steller and control sites. Black bars indicate Steller haulout sites. Grey bars are control sites. With the exception of July 2002-control 33 m depth which was unsampled, zero values exist (no fish seen on transects) where no bars are shown. There was no significant difference between Steller and control sites [F(4,185) =1.34, p=0.25]. There were significant differences between sampling periods [F(4,185) =3.19, p=0.01], and depths [F(4,185) =6.54, p=<0.01] [Table A10].

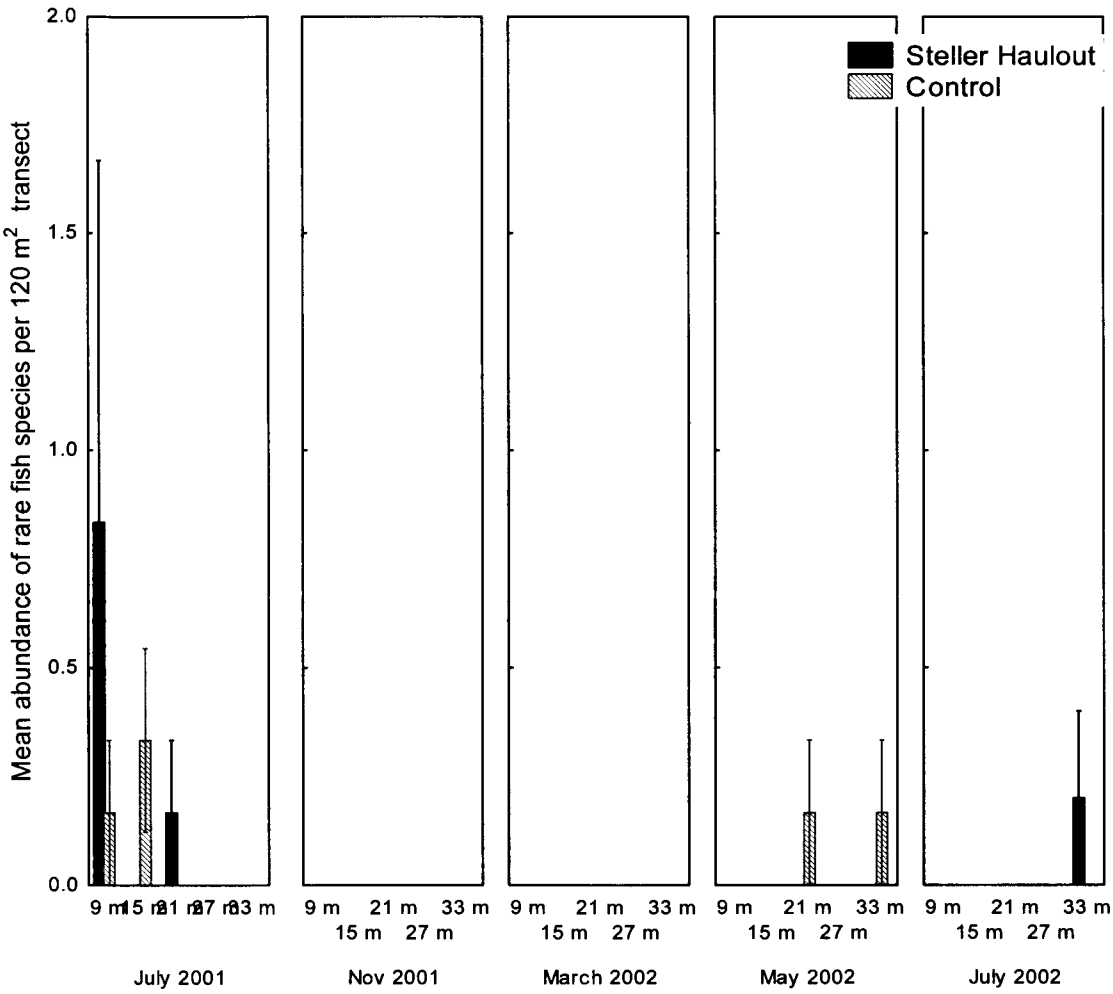

Figure 12: Mean (+/- SE) abundance of rare fish species per 120 m^2 transect. Data for depth and sampling date separated into Steller and control sites. Black bars indicate Steller haulout sites. Grey bars are control sites. With the exception of July 2002-control 33 m depth which was unsampled, zero values exist (no fish seen on transects) where no bars are shown. There was no significant difference between Steller haulouts and control sites [F(4,185) =0.09, p=0.76] or between depths [F(4,185) =0.59, p=0.67]. There was a significant difference between sampling periods [F(4,185) =2.48, p=0.05] [Table A11].

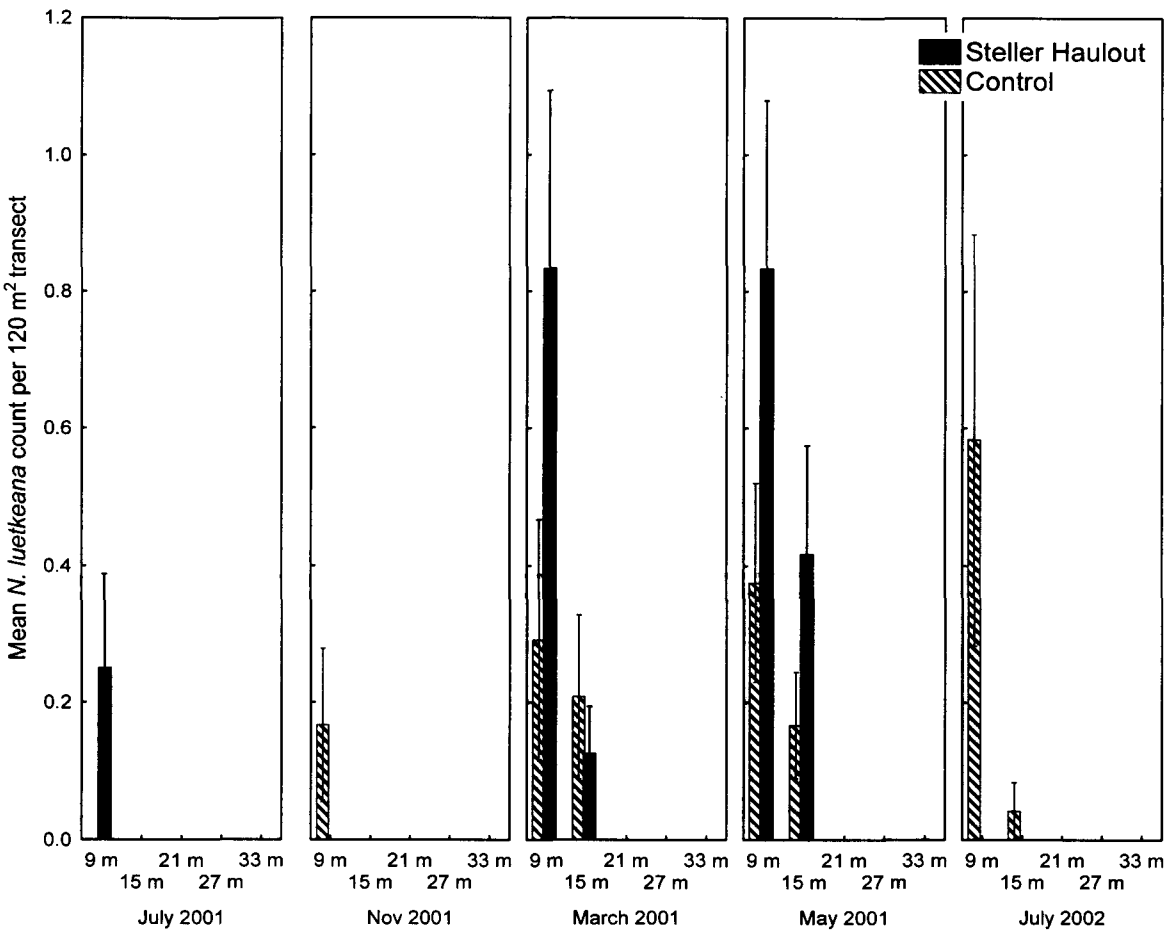

Figure 13: Mean (+/- SE) *Nereocystis leutkeana* count per 120 m^2 transect. Data for depth and sampling date separated into Steller and control sites. Black bars indicate Steller haulout sites. Grey bars are control sites. With the exception of July 2002-control 33 m depth which was unsampled, zero values exist (no kelp seen on transects) where no bars are shown. There was no significant difference between Steller and control sites [F(2, 185) =0.00, p=0.96]. There were significant differences between sampling periods [F(4, 185) =12.97, p=<0.01], and depths [F(4,185)=5.69, p=<0.01] [Table A12].

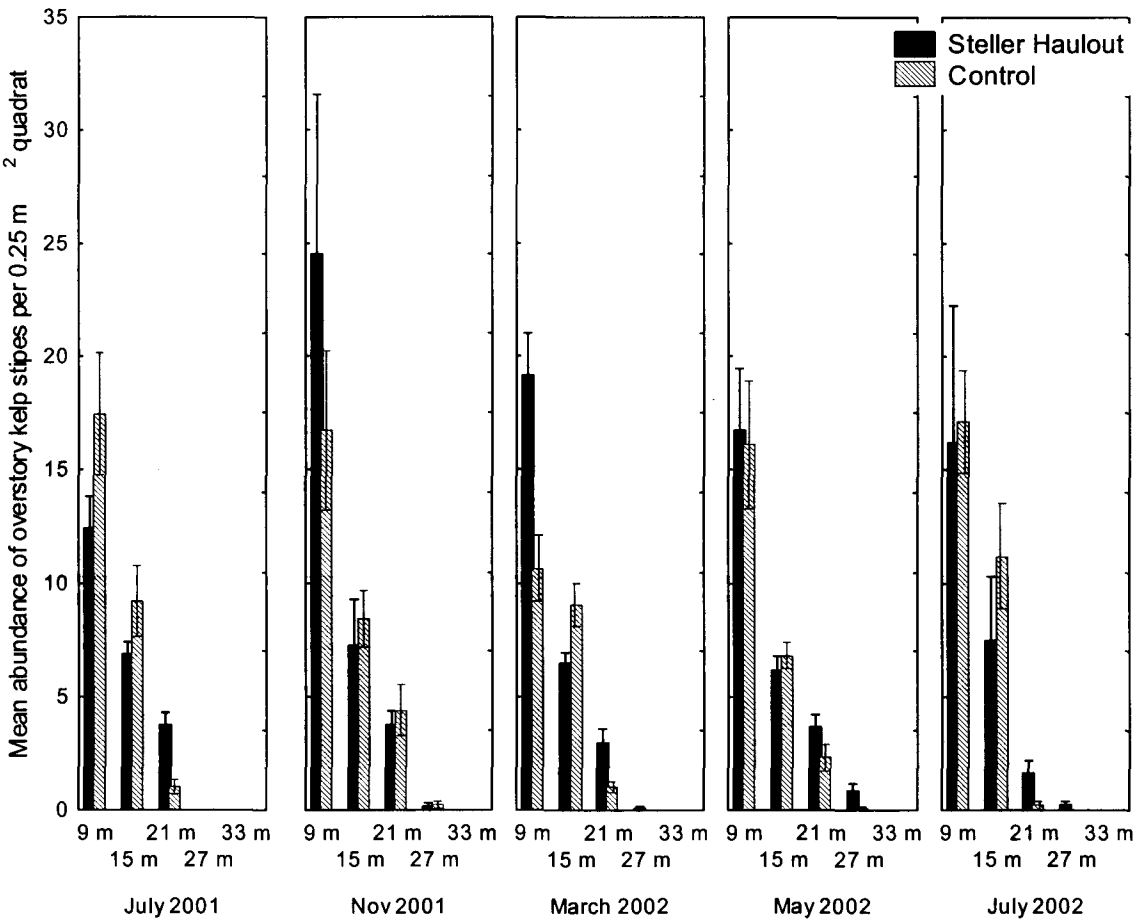

Figure 14: Mean (+/- SE) abundance of overstory algal cover. Data for depth and sampling date separated into Steller and control sites. Bars indicate total count of brown algal stipes in 0.25 m^2 quadrats. Black bars are Steller haulout sites. Grey bars are control sites. With the exception of July 2002-control 33 m depth which was unsampled, zero values exist (no algal stipes in quadrats) where no bars are shown. No significant difference exists between Steller haulout and control sites [F(1,1005)=0.02, p= 0.88]. No significant difference found between sampling periods [F(4, 1005)=0.97, p=0.42]. Significant differences were found between sampling depths: [F(4,1005) =907.15, p=<0.01] [Table 5, Table A13].

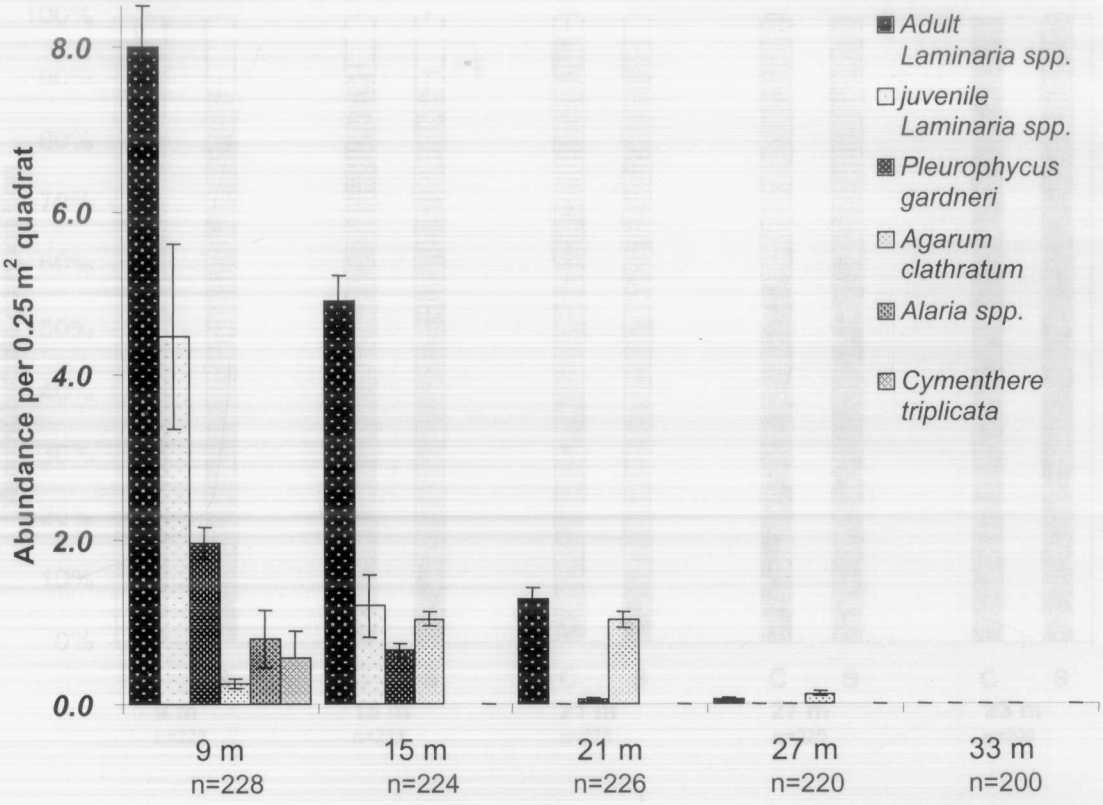

Figure 15: Overstory kelp stipes mean (+/- SE) species abundance. Bars indicate total count of stipes in 0.25 m^2 quadrats by depth, all sampling periods combined. Zero values exist (no algal stipes in the quadrats) where no bars are shown. Number of quadrats sampled at each depth is indicated by n.

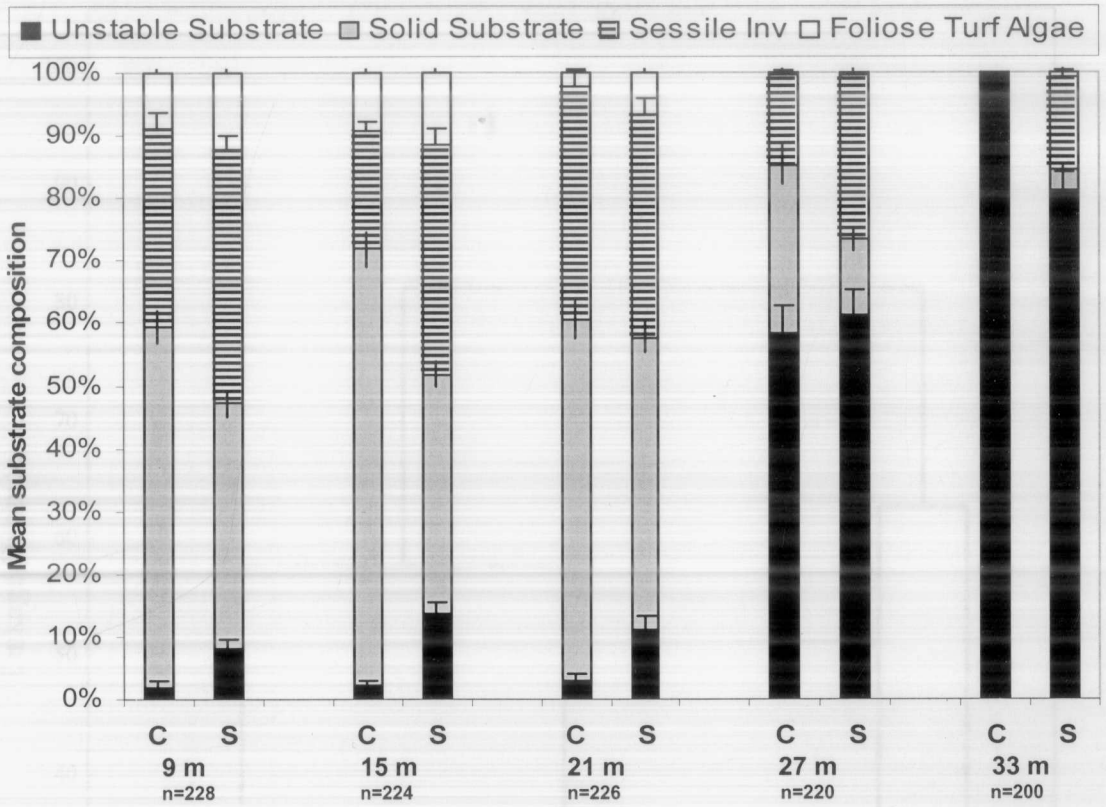

Figure 16: Mean (+/- SE) composition of bottom substrate. Amount of unstable, solid, sessile invertebrate and foliose algae, composing the seafloor at sampling depths of Steller haulout (S) and control sites (C) is given in % of total. Sample size for each sampling depth is given.

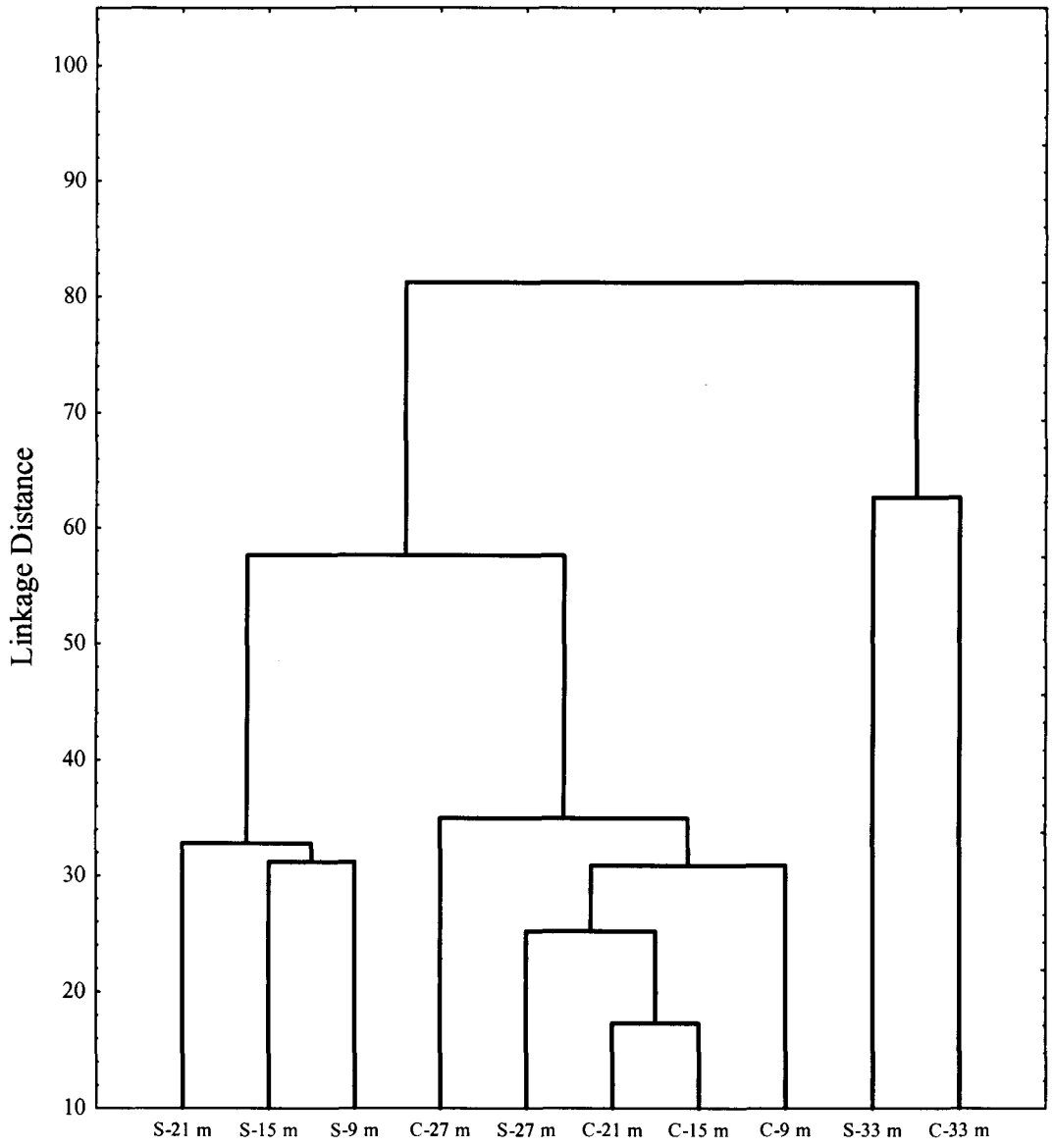

Figure 17: Fish cluster analysis. Data grouped by depth and Steller haulout and control sites, all sampling periods combined. Steller haulout sampling depths indicated with "S", control sites with "C". Single linkage distance from Bray-Curtis dissimilarities matrix. Notice Grouping of Steller 9, 15 and 21 m depths.

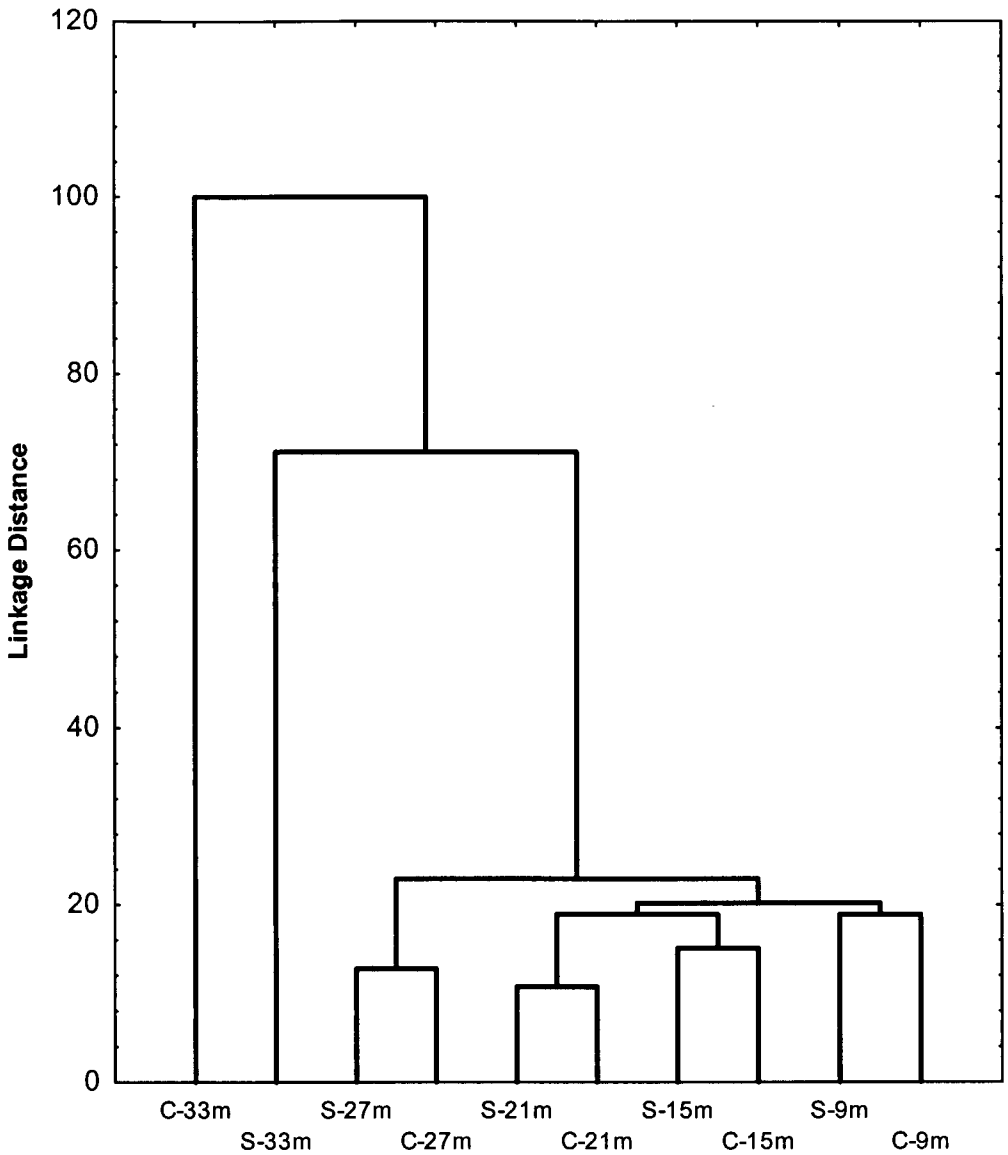

Figure 18: Algal habitat cluster analysis. Data grouped by Steller haulout sampling depths and control sampling depths. Steller indicated with an "S", control sites with "C". Single linkage distance from Bray-Curtis dissimilarities matrix. All Algal habitat data were combined for analysis. Notice groupings are according to depth intervals not Steller haulout and control.

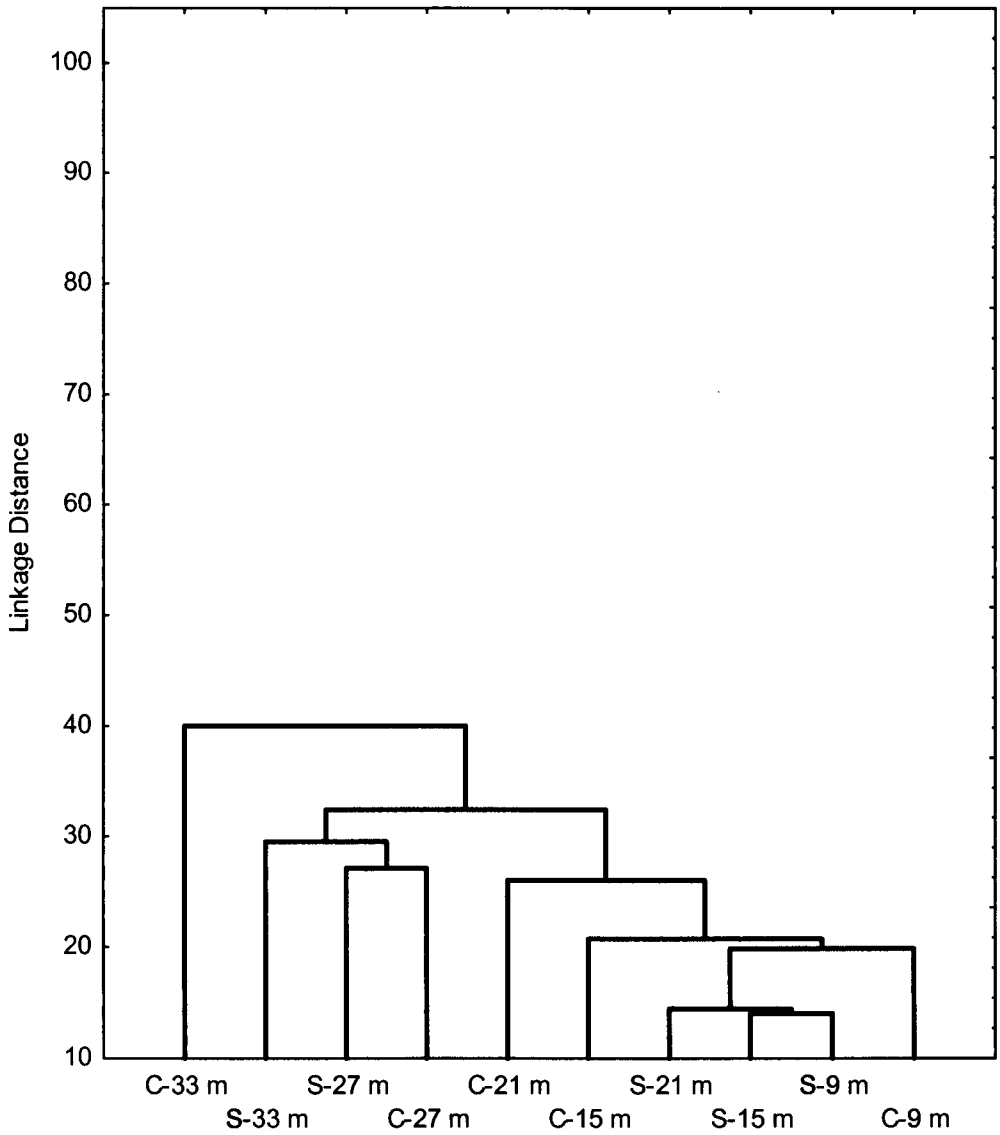

Figure 19: Substrate cluster analysis. Data were grouped by Steller haulout sampling depths and control sampling depths. Steller indicated with an "S", control sites with "C". Single linkage distance from Bray-Curtis dissimilarities matrix. All substrate data were combined for analysis.

Table 1: Analysis groups and taxa list for each group.

Analysis Group	Scientific Name	Common Name
Greenlings:	**Hexagrammidae**	
	Hexagrammos decagrammus	Kelp greenling
	Hexagrammos lagocephalus	Rock greenling
	Hexagrammos stelleri	White spotted greenling
	Ophiodon elongatus	Ling cod
	Hexagrammos spp.	Juvenile greenling
Rockfish:	**Scorpaenidae**	
	Sebastes melanops	Dusky rockfish
	Sebastes ciliatus	Black rockfish
	Sebastes spp. Juvenile	Juvenile rockfish
Sculpins:	**Cottidae**	
	Hemilepidotus hemilepidotus	Red Irish lord
	Hemilepidotus jordani	Yellow Irish lord
	Icelinus borealis	Northern sculpin
	Hemilepidotus papilio	Butterfly sculpin
		Unknown sculpin
Ronquils:	**Bathymasteridae**	
	Bathymaster spp.	Unknown ronquil
Flatfish:	**Pleuronectidae**	
	Lepidopsetta spp.	Rock sole
	Platichthys stellatus	Starry flounder
Rare species:	**Agonidae**	
	Podothecus accipenserinus	Sturgeon poacher
	Aulorhynchidae	
	Aulorhynchus flavidus	Tubesnout
	Cyclopteridae	
	Aptocyclus verntricosus	Smooth lump sucker
	Gadidae	
	Gadus macrocephalus	Pacific cod
	Stichaeidae	
	Poroclinus rothrocki	White barred prickleback
Schooling Fish:	**Gadidae**	
	Gadus sp.	Juvenile gadids
	Ammodytidae	
	Ammodytes hexapterus	Sandlance

Table 2: Counts and frequency of occurrence of fish. Data given in bold are total combined counts and frequencies of occurrence for analysis groups.

Common Name	Total Count	Frequency of Occurrence
Total Greenling:	**297**	**129**
Kelp greenling	235	112
Rock greenling	29	24
White spotted greenling	26	17
Ling cod	4	4
Juvenile greenling	3	3
Total Rockfish:	**510**	**53**
Black rockfish	492	49
Dusky rockfish	4	3
Juvenile rockfish	14	5
Total Sculpin:	**70**	**45**
Red Irish lord	34	18
Yellow Irish lord	22	16
Northern sculpin	9	7
Butterfly sculpin	2	1
Unknown sculpin	3	3
Total Ronquil:	**43**	**24**
Total flatfish:	**24**	**13**
Rock Sole	23	12
Starry Flounder	1	1
Total rare species:	**12**	**8**
Sturgeon poacher	1	1
Tubesnout	3	3
Smooth lump sucker	1	1
Pacific cod	1	1
Juvenile Gadid	5	1
White barred prickleback	1	1
TOTALS:	**956**	**188**

Table 3: Mean abundance of fish analysis groups. Results shown separated into Steller haulout and control sites. All p values given are from Type I GLMs on transformed data (see Tables A2-A10 for complete univariate results for fish analysis groups). Significant results are given in bold type.

	Steller Haulout			Control			
Analysis group:	**Mean**	**Std Dev**	**n**	**Mean**	**Std Dev**	**n**	**p**
Greenling	1.4	0.2	149	0.7	0.1	129	**<0.01**
Rockfish	0.6	0.3	149	3.2	0.7	129	**<0.01**
Sculpins	0.3	0.1	149	0.3	0.1	129	0.78
Ronquils	0.1	0.1	149	0.2	0.1	129	**0.01**
Flatfish	0.1	0.0	149	0.1	0.1	129	0.25
Rares	0.1	0.0	149	0.0	0.0	129	0.76

Table 4: Schooling fish frequency of occurrence. Data is shown for Steller haulout (SSL) and control (C) sites for each sampling period. The data represent number of transects when schooling fish were observed (i.e., not the number of fish schools observed). Sandlance schools are indicated by (S), Juvenile Gadids with (G). Kolmogorov-Smirnov d = 0.47, $p < 0.05$. No data for July 2002 sampling period 33 m depth.

	July 2001		**Nov 2001**		**March 2002**		**May 2002**		**July 2002**	
	SSL	**C**	**SSL**	**C**	**SSL**	**C**	**SSL**	**C**	**SSL**	**C**
9 m	2 (G)	1 (S)	0	0	0	0	0	0	0	0
15 m	2 (G S)	0	0	0	0	0	0	0	0	0
21 m	2 (S)	0	0	0	0	0	0	0	0	0
27 m	3 (S)	0	0	0	0	1 (S)	0	0	0	0
33 m	3 (S)	0	0	0	0	0	0	0	1 (G)	

Table 5: Tukey comparisons for overstory kelp density. Test was done on the total overstory kelp stipes per 0.25 m^2 quadrat, transformed with $Log_{10}(X + 1)$. Differences between Sample Depths F(4,1028)= 943.27, p=<0.01. Approximate probabilities for *Post-hoc* tests error: Between MS = .05580, df = 1028.0. Significant results are in bold print.

Depth	9 m	15 m	21 m	27 m	33 m
9 m		**<0.01**	**<0.01**	**<0.01**	**<0.01**
15 m			**<0.01**	**<0.01**	**<0.01**
21 m				**<0.01**	**<0.01**
27 m					0.41
33 m					

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Appendix A

Table A1: Number of Samples (n). Total number of transects (fish counts and *Nereocystis* counts) and quadrats (habitat) by sampling period, depth and Steller haulout (S) and Control (C) sites.

Sampling periods:	Depth	Haulout or Control	Transect	Quadrats and RPC
Jul-01	9 m	S	6	24
		C	6	24
	15 m	S	6	24
		C	6	24
	21 m	S	6	22
		C	6	24
	27 m	S	6	24
		C	6	23
	33 m	S	6	24
		C	6	24
Nov-01	9 m	S	6	24
		C	3	12
	15 m	S	6	24
		C	3	12
	21 m	S	6	24
		C	3	12
	27 m	S	6	24
		C	3	12
	33 m	S	6	24
		C	3	12
Mar-02	9 m	S	6	24
		C	6	24
	15 m	S	6	24
		C	6	24
	21 m	S	6	24
		C	6	24
	27 m	S	6	24
		C	6	23
	33 m	S	6	24
		C	6	24
May-02	9 m	S	6	24
		C	6	24
	15 m	S	6	24
		C	6	24
	21 m	S	6	24
		C	6	24
	27 m	S	6	24
		C	6	23
	33 m	S	6	24
		C	6	24
Jul-02	9 m	S	6	24
		C	6	24
	15 m	S	6	20
		C	6	24
	21 m	S	6	24
		C	6	24
	27 m	S	6	24
		C	6	19
	33 m	S	5	20
		C	0	0

Table A2: Total fish abundance univariate results. Data used are total counts of fish per transect, transformed with $Log_{10}(X + 1)$ for analysis with Type 1, Sequential GLM. Significant results are given in bold type. (Site) is nested in the Steller Haulout/Control effect. * indicates an interaction term.

Total fish abundance	Degrees of Freedom	SS	MS	F	p
Intercept	1	47.31	47.31	777.92	**0.00**
Steller Haulout /Control	1	0.52	0.52	8.52	**<0.01**
(Site)	2	0.44	0.22	3.61	**0.03**
Sample Period	4	5.01	1.25	20.59	**<0.01**
Depth	4	6.11	1.53	25.13	**<0.01**
Steller *Sample Period	4	2.43	0.61	9.98	**<0.01**
Steller *Depth	4	0.87	0.22	3.60	**0.01**
Sample Period*Depth	16	3.32	0.21	3.41	**<0.01**
Steller *Sample Period*Depth	15	3.42	0.23	3.75	**<0.01**
Site*Sample Period	7	2.44	0.35	5.72	**<0.01**
Site*Depth	8	3.02	0.38	6.21	**<0.01**
Site*Sample Period*Depth	27	4.98	0.18	3.03	**<0.01**
Error	185	11.25	0.06		
Total	277	43.81			

Table A3: Tukey differences between sample periods for total fish abundance

	July-01	Nov-02	March-02	May-02	July-02
July-01		**<0.01**	**<0.01**	**<0.01**	0.99
Nov-02			0.76	0.99	**<0.01**
March-02				0.95	**<0.01**
May-02					**<0.01**
July-02					

Table A4: Tukey differences between depths for total fish abundance

Depth	9 m	15 m	21 m	27 m	33 m
9 m		0.11	**<0.01**	0.83	**<0.01**
15 m			0.26	**<0.01**	**<0.01**
21 m				**<0.01**	**<0.01**
27 m					**<0.01**
33 m					

Table A5: Fish species richness univariate results. Data used are counts of number of species seen on a transect, transformed with $Log_{10}(X + 1)$ before analysis with Type 1, Sequential GLM. Significant results are given in bold type. (Site) is nested in the Steller Haulout/Control effect. * indicates an interaction term.

Fish Species Richness	Degrees of Freedom	SS	MS	F	p
Intercept	1	20.77	20.77	885.42	0.00
Steller Haulout / Control	1	0.05	0.05	2.14	0.15
(Site)	2	0.20	0.10	4.23	**0.02**
Sample Period	4	1.03	0.26	10.92	**<0.01**
Depth	4	2.27	0.57	24.14	**<0.01**
Steller *Sample Period	4	0.41	0.10	4.36	**<0.01**
Steller *Depth	4	0.10	0.02	1.05	0.38
Sample Period*Depth	16	1.09	0.07	2.91	**<0.01**
Steller *Sample Period*Depth	15	0.66	0.04	1.88	**0.03**
Site*Sample Period	7	0.34	0.05	2.05	**0.05**
Site*Depth	8	0.91	0.11	4.85	**<0.01**
Site*Sample Period*Depth	27	1.39	0.05	2.19	**<0.01**
Error	185	4.34	0.02		
Total	277	12.78			

Table A6: Greenling analysis group univariate results. Data transformed with $Log_{10}(X + 1)$ before analysis with Type 1, Sequential GLM. Significant results are given in bold type. (Site) is nested in the Steller Haulout/Control effect. * indicates an interaction term.

Greenling Analysis group	Degrees of Freedom	SS	MS	F	p
Intercept	1	13.1	13.10	292.20	**0**
Steller Haulout / Control	1	0.79	0.79	17.63	**<0.01**
(Site)	2	0.15	0.07	1.64	0.20
Sample Period	4	0.63	0.16	3.53	**0.01**
Depth	4	3.42	0.85	19.04	**<0.01**
Steller *Sample Period	4	0.26	0.06	1.44	0.22
Steller *Depth	4	0.11	0.03	0.60	0.66
Sample Period*Depth	16	1.04	0.07	1.45	0.12
Steller *Sample Period*Depth	15	0.81	0.05	1.21	0.27
Site*Sample Period	7	0.66	0.09	2.12	**0.04**
Site*Depth	8	1.92	0.24	5.36	**<0.01**
Site*Sample Period*Depth	27	1.89	0.07	1.56	**0.05**
Error	185	8.30	0.04		
Total	277	19.98			

Table A7: Rockfish analysis group univariate results. Data transformed with Log_{10} (X + 1) before analysis with Type 1, Sequential GLM. Significant results are given in bold type. (Site) is nested in the Steller Haulout/Control effect. * indicates an interaction term.

Rockfish analysis group	Degrees of Freedom	SS	MS	F	p
Intercept	1	6.61	6.61	137.58	**0**
Steller Haulout / Control	1	2.66	2.66	55.48	**<0.01**
(Site)	2	1.74	0.87	18.09	**<0.01**
Sample Period	4	4.47	1.12	23.28	**<0.01**
Depth	4	1.87	0.47	9.71	**<0.01**
Steller *Sample Period	4	3.81	0.95	19.82	**<0.01**
Steller *Depth	4	2.77	0.69	14.40	**<0.01**
Sample Period*Depth	16	2.42	0.15	3.15	**<0.01**
Steller *Sample Period*Depth	15	2.86	0.19	3.97	**<0.01**
Site*Sample Period	7	1.57	0.22	4.68	**<0.01**
Site*Depth	8	1.72	0.22	4.48	**<0.01**
Site*Sample Period*Depth	27	3.06	0.11	2.36	**<0.01**
Error	185	8.88	0.05		
Total	277	37.83			

Table A8: Sculpin analysis group univariate results. Data transformed with Log_{10} (X + 1) before analysis with Type 1, Sequential GLM. Significant results are given in bold type. (Site) is nested in the Steller Haulout/Control effect. * indicates an interaction term.

Sculpin Analysis group	Degrees of Freedom	SS	MS	F	p
Intercept	1	1.09	1.09	59.70	0
Steller Haulout / Control	1	0.00	0.00	0.08	0.78
(Site)	2	0.15	0.08	4.17	**0.02**
Sample Period	4	0.26	0.07	3.59	**0.01**
Depth	4	0.27	0.07	3.74	**0.01**
Steller *Sample Period	4	0.07	0.02	0.89	0.47
Steller *Depth	4	0.30	0.08	4.13	**<0.01**
Sample Period*Depth	16	0.26	0.02	0.90	0.57
Steller *Sample Period*Depth	15	0.48	0.03	1.73	**0.05**
Site*Sample Period	7	0.46	0.07	3.60	**<0.01**
Site*Depth	8	0.17	0.02	1.18	0.32
Site*Sample Period*Depth	27	0.56	0.02	1.12	0.32
Error	185	3.39	0.02		
Total	277	6.37			

Table A9: Ronquils analysis group univariate results. Data transformed with $Log_{10}(X + 1)$ before analysis with Type 1, Sequential GLM. Significant results are given in bold type. (Site) is nested in the Steller Haulout/Control effect. * indicates an interaction term.

Ronquil analysis group	Degrees of Freedom	SS	MS	F	p
Intercept	1	0.34	0.34	36.01	0
Steller Haulout / Control	1	0.08	0.08	8.06	**0.01**
(Site)	2	0.06	0.03	3.24	**0.04**
Sample Period	4	0.41	0.10	10.87	**<0.01**
Depth	4	0.11	0.03	2.77	**0.03**
Steller *Sample Period	4	0.21	0.05	5.65	**<0.01**
Steller *Depth	4	0.10	0.02	2.52	**0.04**
Sample Period*Depth	16	0.34	0.02	2.22	**0.01**
Steller *Sample Period*Depth	15	0.22	0.01	1.54	0.09
Site*Sample Period	7	0.35	0.05	5.28	**<0.01**
Site*Depth	8	0.12	0.02	1.64	0.12
Site*Sample Period*Depth	27	0.56	0.02	2.20	**<0.01**
Error	185	1.76	0.01		
Total	277	4.32			

Table A10: Flatfish analysis group univariate results. Data transformed with Log_{10} (X + 1) before analysis with Type 1, Sequential GLM. Significant results are given in bold type. (Site) is nested in the Steller Haulout/Control effect. * indicates an interaction term.

Flatfish analysis group	Degrees of Freedom	SS	MS	F	p
Intercept	1	0.11	0.11	16.78	0.00
Steller Haulout /Control	1	0.01	0.01	1.34	0.25
(Site)	2	0.08	0.04	6.27	**<0.01**
Sample Period	4	0.08	0.02	3.19	**0.01**
Depth	4	0.17	0.04	6.54	**<0.01**
Steller *Sample Period	4	0.05	0.01	1.88	0.12
Steller *Depth	4	0.09	0.02	3.55	**0.01**
Sample Period*Depth	16	0.18	0.01	1.74	**0.04**
Steller *Sample Period*Depth	15	0.16	0.01	1.66	0.06
Site*Sample Period	7	0.08	0.01	1.82	0.09
Site*Depth	8	0.19	0.02	3.63	**<0.01**
Site*Sample Period*Depth	27	0.25	0.01	1.44	0.08
Error	185	1.18	0.01		
Total	277	2.51			

Table A11: Rare fish analysis group univariate results. Data used are number of species seen per transect, transformed with $Log_{10}(X + 1)$ before analysis with Type 1, Sequential GLM. Significant results are given in bold type. (Site) is nested in the Steller Haulout/Control effect. * indicates an interaction term.

Rare fish analysis group	Degrees. of Freedom	SS	MS	F	p
Intercept	1	0.03	0.03	6.83	0.01
Steller Haulout /Control	1	0.00	0.00	0.09	0.76
(Site)	2	0.00	0.00	0.49	0.61
Sample Period	4	0.04	0.01	2.48	**0.05**
Depth	4	0.01	0.00	0.59	0.67
Steller *Sample Period	4	0.01	0.00	0.46	0.77
Steller *Depth	4	0.01	0.00	0.57	0.69
Sample Period*Depth	16	0.09	0.01	1.22	0.26
Steller *Sample Period*Depth	15	0.05	0.00	0.81	0.66
Site*Sample Period	7	0.01	0.00	0.31	0.95
Site*Depth	8	0.04	0.00	1.02	0.42
Site*Sample Period*Depth	27	0.14	0.01	1.16	0.28
Error	185	0.81	0.00		
Total	277	1.21			

Table A12: Canopy kelp stipes univariate results. Data transformed with $Log_{10}(X + 1)$ for analysis with Type 1, Sequential GLM. Significant results are given in bold type. (Site) is nested in the Steller Haulout/Control effect. * indicates an interaction term.

Canopy kelp	Degrees of Freedom	SS	MS	F	p
Intercept	1	1.44	1.44	111.63	0.00
Steller Haulout / Control	1	0.00	0.00	0.00	0.96
(Site)	2	0.00	0.00	0.12	0.89
Sample Period	4	0.67	0.17	12.97	**<0.01**
Depth	4	2.93	0.73	56.78	**<0.01**
Steller *Sample Period	4	0.29	0.07	5.69	**<0.01**
Steller *Depth	4	0.01	0.00	0.10	0.98
Sample Period*Depth	16	1.16	0.07	5.64	**<0.01**
Steller *Sample Period*Depth	15	0.85	0.06	4.41	**<0.01**
Site*Sample Period	7	0.27	0.04	2.99	**0.01**
Site*Depth	8	0.26	0.03	2.49	**0.01**
Site*Sample Period*Depth	27	0.84	0.03	2.43	**<0.01**
Error	185	2.37	0.01		
Total	277	9.65			

Table A13: Overstory kelp stipes univariate results. Data $\log_{10}(X + 1)$ transformed prior to analysis with a Type 1, Sequential GLM. Significant results are given in bold type. (Site) is nested in the Steller Haulout/Control effect. * indicates an interaction term.

Overstory Kelp	Degrees of Freedom	SS	MS	F	p
Intercept	1	260.10	260.10	4556.90	0.00
Steller Haulout / Control	1	0.00	0.00	0.02	0.88
(Site)	2	3.36	1.68	29.47	**<0.01**
Sample Period	4	0.22	0.06	0.97	0.42
Depth	4	207.11	51.78	907.15	**<0.01**
Steller *Sample Period	4	1.51	0.38	6.61	**<0.01**
Steller *Depth	4	3.58	0.89	15.67	**<0.01**
Sample Period*Depth	16	3.91	0.24	4.28	**<0.01**
Steller *Sample Period*Depth	15	2.40	0.16	2.80	**<0.01**
Site*Sample Period	7	3.01	0.43	7.52	**<0.01**
Site*Depth	8	4.25	0.53	9.30	**<0.01**
Site*Sample Period*Depth	27	7.83	0.29	5.08	**<0.01**
Error	1005	57.36	0.06		
Total	1097	294.53			

Table A14: Turf algae univariate results. Data arcsine($\sqrt{x}$) transformed prior to analysis with a Type 1, Sequential GLM. Significant results are given in bold type. (Site) is nested in the Steller Haulout/Control effect. * indicates an interaction term.

Turf algae	Degrees of Freedom	SS	MS	F	p
Intercept	1	22.15	22.15	1116.63	**0.00**
Steller Haulout / Control	1	0.35	0.35	17.41	**<0.01**
(Site)	2	1.46	0.73	36.84	**<0.01**
Sample Period	4	1.69	0.42	21.30	**<0.01**
Depth	4	9.57	2.39	120.57	**<0.01**
Steller *Sample Period	4	0.14	0.04	1.79	0.13
Steller *Depth	4	0.26	0.06	3.25	**0.01**
Sample Period*Depth	16	2.76	0.17	8.68	**<0.01**
Steller *Sample Period*Depth	15	3.37	0.22	11.32	**<0.01**
Site*Sample Period	7	0.60	0.09	4.29	**<0.01**
Site*Depth	8	2.42	0.30	15.25	**<0.01**
Site*Sample Period*Depth	27	1.33	0.05	2.48	**<0.01**
Error	1005	20.03	0.02		
Total	1097	43.97			